Middle Eocene Brackish-Marine Mollusks from the Matilija Sandstone at Matilija Hot Springs, Ventura County, Southern California

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ABSTRACT. This study is the first detailed account of within-habitat, brackish-marine Eocene mollusks in the Transverse Ranges of southern California. The fossils are from the lower middle Eocene ("Transition Stage") upper part of the Matilija Sandstone at Matilija Hot Springs, near Ojai, Ventura County, southern California. Sixteen species (eight gastropods and eight bivalves) were found, and three of these are new: a gastropod *Tympanotonos (T.) californicus* new species, and two bivalves *Neotrapezium californicum* new species and *Corbicula jestesi* new species. This is the first confirmed record of *Tympanotonos* in North America and the first record of *Neotrapezium* in North America. The megafauna contains the earliest known record of the gastropod "*Melanatria*" *markleyensis* and the latest known records of the bivalves *Barbatia (B.) morsei,* "*Tellina*" *joaquinensis,* and "*Tellina*" *domenginensis.*

The local brackish-marine section, which is approximately 55 m thick, was deposited on the upper part of a deltaic complex and consists of lagoonal mudstones and siltstones alternating with beach or barrier-bar sandstones. Within the lagoonal rocks are interbeds of coastal-sabkha limestone and gypsum, as well as subaerial? redbeds. Mollusks are abundant within the lagoonal rocks and represent parautochthonous assemblages that have undergone varying amounts of postmortem transport but were not moved out of their original lagoonal habitat of mud and silt. Other megafossils are rare. Some of the molluscan assemblages consist of up to 13 species of mollusks. All of the shells are unabraded, and many are complete. Other assemblages consist entirely of concentrations of either the bivalve *Pelecyora aequilateralis* or the bivalve *Cuneocorbula torreyensis.* Both types of concentrations consist of tightly packed, unabraded single valves. Within some of the beach and barrier-bar sandstones are fragments of the oyster *Acutostrea idriaensis idriaensis,* which were transported out of their muddy lagoonal habitat.

INTRODUCTION

Brackish-marine rocks are uncommon in the rock record because they are highly susceptible to erosion. A local, 55-m-thick section of middle Eocene ("Transition Stage") brackish-marine rocks in the upper part of the Matilija Sandstone at Matilija Hot Springs,located 6.5 km northwest of the city of Ojai in Ventura County, southern California (Fig. 1A), was preserved because it underwent subsidence and was overlain by a protective cover of deeper marine deposits. Kerr and Schenck (1928) were the first to recognize the brackish-marine aspect of these rocks. They reported a "lignitic facies" with abundant specimens of mollusks near Matilija Hot Springs, but they believed that the facies was confined to a single bed. Jestes (1963) was the first to more fully recognize the extent of this brackish-marine paleoenvironment, which he documented by means of a preliminary study of the fossil mollusks. Link (1975) and Link and Welton (1982) did sedimentological studies that confirmed Jestes' interpretation. They utilized Jestes' preliminary molluscan studies but did not elaborate on them. Molluscan fossils are abundant and, in many cases, well preserved in these rocks, but until this present study, they were not analyzed in detail. Squires (1991a, 1998) worked on two of the gastropod species from these rocks, namely *Potamides (Potamidopsis) californica* Squires, 1991a, and *Loxotrema turritum* Gabb, 1868. In recent years, I have become increasingly interested in brackish-marine Eocene rocks, and my students and I have returned on many occasions to the Matilija Hot Springs section to undertake more detailed studies. The goal of this present article is to fully document, for the first time, all the mollusks and to give the details of their stratigraphic distribution in the study area.

The molluscan stage terminology used here stems from Clark and Vokes (1936), who proposed five mollusk-based provincial Eocene stages: "Meganos" (uppermost Paleocene to lowermost Eocene), "Capay" (middle lower Eocene), "Domengine" (upper lower to lower middle Eocene), "Transition" (lower middle Eocene), and "Tejon" (middle middle Eocene to upper Eocene). Givens (1974) modified the use of the "Capay Stage." The stage names are

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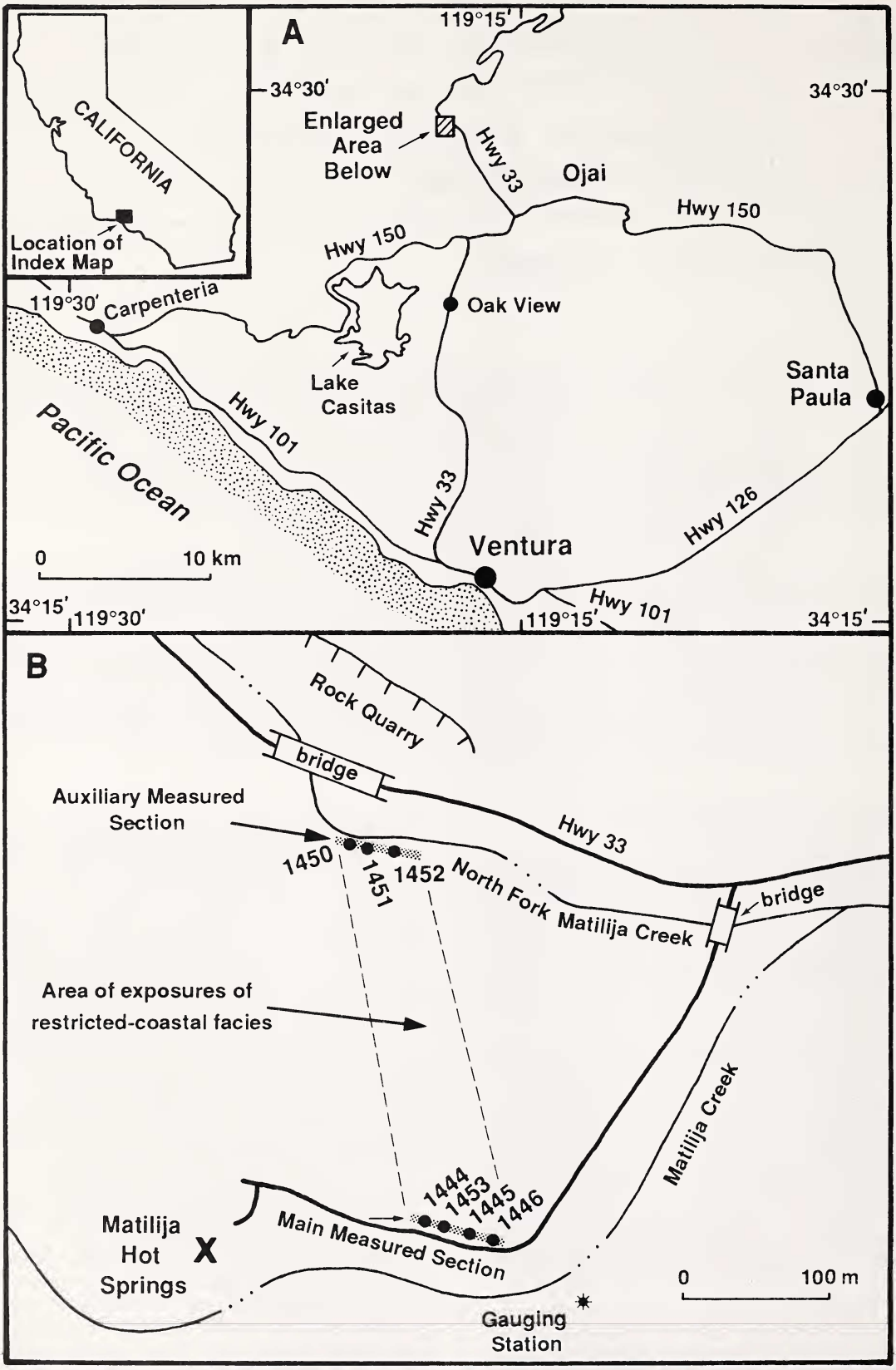


Figure 1. Index map showing (A) the generalized location and (B) the detailed location of Matilija Hot Springs, Ventura County, southern California. Part (B) also shows locations of the measured sections and of the CSUN megafossil localities.

in quotes because they are informal terms. Squires (in press) correlated all the stages, except the upper part of the "Tejon Stage," to the standard calcareous nannofossil zonation.

In this present article, the term "brackish marine" refers to restricted waters with salinities lower than those of normal ocean waters. Furthermore, the term "brackish marine" refers to waters landward of beaches or barrier bars but with some connection to the shallow-marine environment. The term "shallow marine" refers to unrestricted, nearshore waters of normal ocean salinity seaward of beaches or barrrier bars.

The following institutional acronyms are used:

ANSP	Academy of Natural Sciences, Philadelphia
CSUN	California State University, Department of Geological Sciences, Northridge
LACM	Natural History Museum of Los Angeles County, Section of Malacology
LACMIP	Natural History Museum of Los Angeles County, Section of Invertebrate Paleontology
MCZ	Museum of Comparative Zoology, Harvard University
UCMP	University of California Museum of Paleontology, Berkeley
UCR	University of California, Riverside
USGS	United States Geological Survey, Reston, Virginia

STRATIGRAPHY

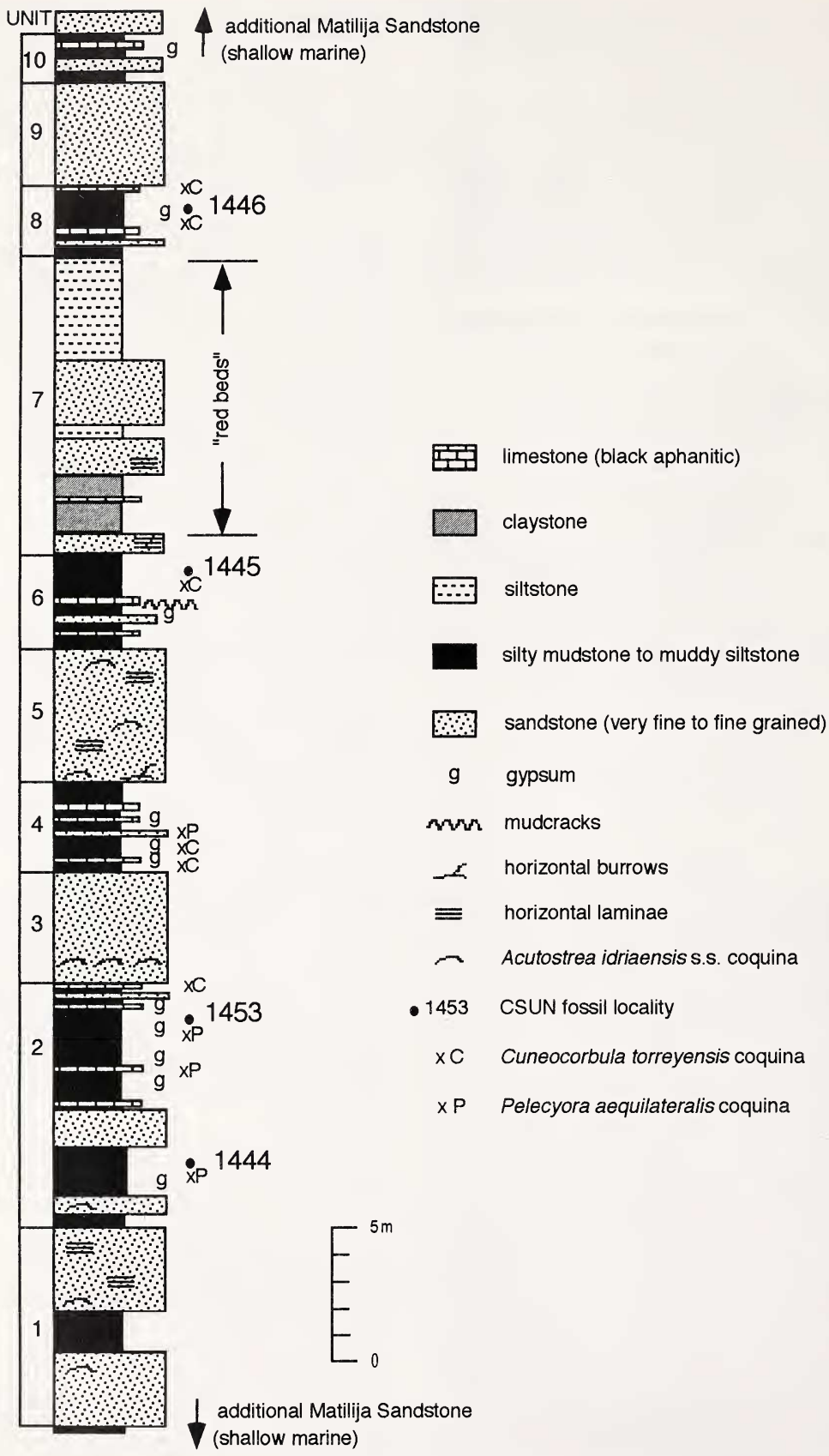
The study area rocks are in the upper part of the Matilija Sandstone and crop out in a small area bounded on the south by a side road leading to the Matilija Hot Springs and on the north by the river bed of the North Fork Matilija Creek, a distance of 270 m (Fig. 1B). This general area is also the type section of the Matilija Sandstone, named by Kerr and Schenck (1928). The study area rocks consist of resistant beds of sandstone, 1 to 5 m thick, alternating with nonresistant, finer grained intervals, about 2 to 7 m thick. These alternating rock types will be referred to as the "restricted-coastal facies." The finer grained intervals consist of complexly interbedded mudstone, fossiliferous mudstone, siltstone, claystone, limestone, and gypsum, as well as stringers of sandstone. Although Link and Welton (1982: fig. 3, section 5) provided a columnar section of the restricted-coastal facies, they did not indicate which beds contain fossils. This present study revealed, for the first time, the stratigraphic distribution of these fossils (Figs. 2, 3).

The most accessible and best exposed section of the restricted-coastal facies is in a roadcut along the north side of the side road leading to Matilija Hot Springs (Fig. 1B). The roadcut exposes a continuous section of nearly vertical beds, and this is where Link and Welton (1982) and Jestes (1963) focused their studies. This is also where I measured my main section (Fig. 2). I did a microstratigraphic study and recorded every change in lithology and every place where fossils were found. The side of the roadcut is steep, and access to some of the beds is extremely limited.

An auxiliary section was measured along the south side of the riverbed of the North Fork of Matilija Creek (Figs. 1B, 3). The lower part of the section is accessible, but the middle part is along the cut-bank side of the creek. Access is difficult when there is considerable water flow in the creek. The upper part of the section is covered. Very steep slopes and dense brush prevent "walking out" of individual beds between the main and the auxiliary measured sections. Although individual beds could not be correlated between the two sections, six stratigraphic units are recognizable at both sections. These units, which are denoted on Figures 2 and 3 as units 1 through 6, consist of alternating sandstone and finer grained units that are similar in terms of lithology and overall fossil content. The finer grained units thin toward the auxiliary section. Additional complex stratigraphic units (7 through 10) are present at the main section, but at the auxiliary section only a single, very thick sandstone and an overlying thick covered interval correspond to units 7 through 10. Unit 7 at the main section is an interval of "red-beds" consisting of unfossiliferous sandstone, siltstone, and claystone beds. In addition to having some red color, rocks in this interval show much variation in color, with gray, maroon, bluish gray, and greenish gray also present.

A few meters of fossiliferous mudstone and interbedded sandstone were temporarily uncovered by recent bulldozing activity in an active rock quarry on the north side of the North Fork of Matilija Creek (Fig. 1B), but private property and safety restrictions make this area inaccessible. Extensive slope wash and dense brush prevent the detection of any more exposures of the study area rocks immediately south of the roadcut along the road to Matilija Hot Springs and immediately north of the rock quarry.

The sandstones in the restricted-coastal facies usually are fine grained, tabular units that are nearly structureless. Some of them are horizontally laminated, and a few have horizontal burrows near their lower contact. Most of the sandstones are not fossiliferous (Figs. 2, 3). The only fossils found in them are scarce fragments of the oyster *Acutostrea idriaensis idriaensis* (Gabb, 1869). The most abundant oyster fragments are in a 10-cm-thick limy sandstone interbed near the base of a 4-m-thick sandstone (unit 3) in the main measured section. In this interbed, the oysters form a coquina consisting of fragments of single valves, which are thick shelled and concave down.


UNIT
10
9
8
7
6
5
4
3
2
1
additional Matilija Sandstone
(shallow marine)
xC
g
1446
xC
"red beds"
1445
xC
g
g
xP
xC
g
xC
xC
g
g
1453
xP
g
g
xP
g
1444
xP
5m
0
additional Matilija Sandstone
(shallow marine)
limestone (black aphanitic)
claystone
siltstone
silty mudstone to muddy siltstone
sandstone (very fine to fine grained)
g gypsum
mudcracks
horizontal burrows
horizontal laminae
Acutostrea idriaensis s.s. coquina
1453 CSUN fossil locality
x C Cuneocorbula torreyensis coquina
x P Pelecyora aequilateralis coquina

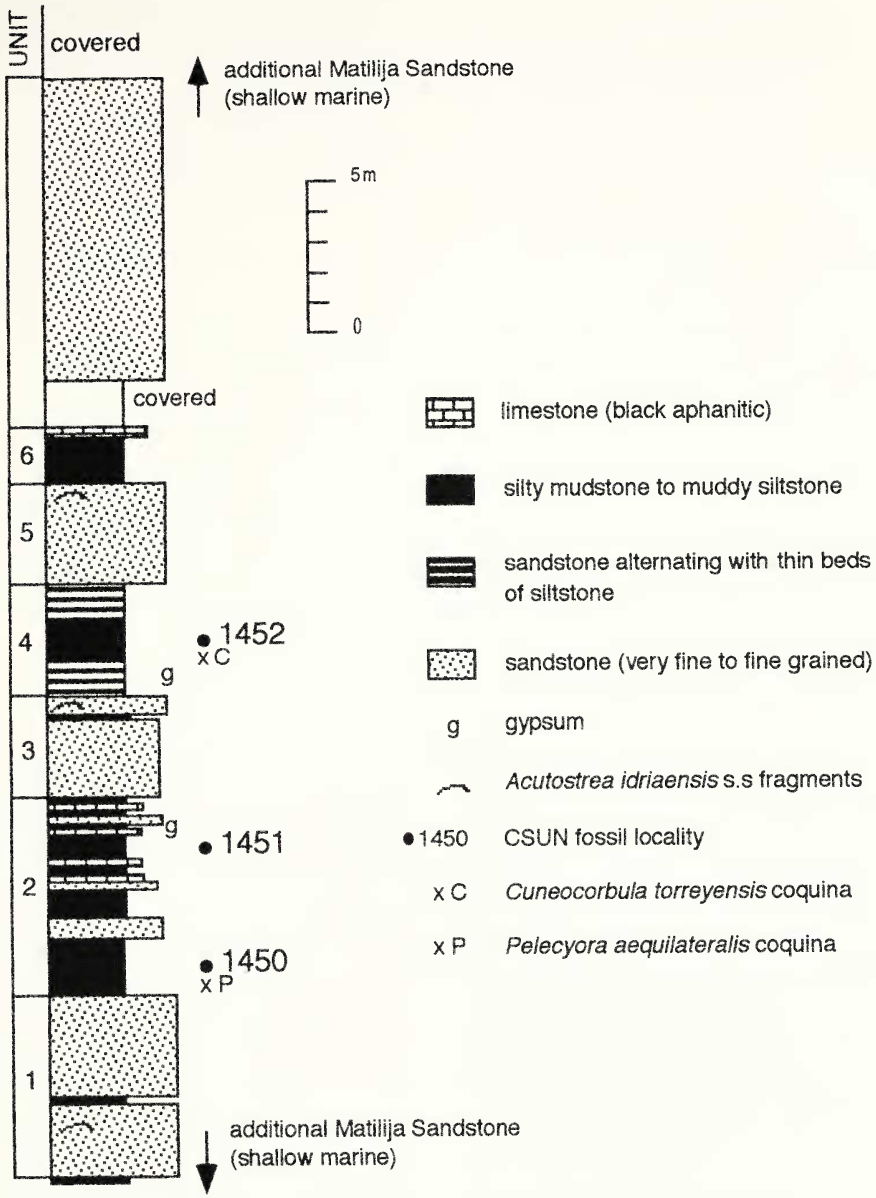


Figure 3. Stratigraphy and CSUN megafossil localities of the restricted-coastal facies in the upper part of the Matilija Sandstone along the auxilary measured section in the Matilija Hot Springs area. See Figure 1 for location of this measured section.

The finer grained intervals in the restricted-coastal facies show much complexity and variation in the vertical sequence of rock types. It is not unusual to have 10 to 12 changes in lithology in just one meter of vertical section, especially where limestone and gypsum are present. The best examples are in units 2 (upper half), 4, 6 (lower half), 8, and 10. In these units, aphanitic limestone and gypsum are complexly interbedded with mudstone, gypsiferous mudstone, limy sandstone, thin sandstone, and, in

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Figure 2. Stratigraphy and CSUN megafossil localities of the restricted-coastal facies in the upper part of the Matilija Sandstone along the main measured section in the Matilija Hot Springs area. See Figure 1 for location of this measured section.

Table 1. Checklist and abundance of brackish-marine mollusks from CSUN localities in the restricted-coastal facies, upper part of the Matilija Sandstone at Matilija Hot Springs. Localities listed from left to right in ascending stratigraphic order. Localities 1450 and 1451 are 270 m (885 ft.) to the north of the other localities. A ≥30 specimens, C = 10–29 specimens, UC = 5–9 specimens, R = 1–4 specimens, — = not found.

Taxa	Localities and abundance						
	1444	1450	1451	1452	1453	1445	1446
Gastropoda							
Crepidula inornata	R	C	—	—	—	C	R
Crommium sp. cf. *C. andersoni*	UC	R	—	—	—	—	—
Loxotrema turritum	C	A	R	R	—	C	R
"*Melanatria*" *markleyensis*	—	—	—	—	—	A	UC
Neverita (*Neverita*) *globosa*	R	R	R	—	—	—	—
Potamides (*Potamidopsis*) *californica*	A	A	C	—	C	UC	C
Pyrgulfera (*P.*) *lajollaensis*	—	UC	—	R	R	UC	R
Typanotonos (*T.*) *californicus* new species	C	A	C	—	A	—	—
Bivalvia							
Acutostrea idriaensis idriaensis	C	C	C	R	—	C	UC
Barbatia (*Barbatia*) *morsei*	R	C	R	—	—	—	—
Corbicula jestesi new species	—	—	—	R	—	A	—
Cuneocorbula torreyensis	—	—	—	A	—	A	—
Neotrapezium californicum new species	UC	A	R	—	UC	UC	R
Pelecyora aequilateralis	A	A	R	—	UC	C	A
"*Tellina*" *domenginesis*	R	C	—	—	—	R	R
"*Tellina*" *joaquinensis*	UC	A	UC	UC	C	A	UC

some cases, fossiliferous mudstone. Fossils in the finer grained intervals are confined to mudstone and siltstone (Figs. 2, 3), but not every mudstone or siltstone contains fossils. Fossils in the finer grained intervals are found in either muddy, thin coquina beds or in less densely packed, muddy fossiliferous beds that immediately overlie most of the coquina beds. The latter contain huge numbers of bivalve specimens of either *Pelecyora aequilateralis* (Gabb, 1869) or *Cuneocorbula torreyensis* (Hanna, 1927), and the specimens are always stacked one upon the other and tightly packed. Although many of these specimens have been crushed by compaction, they are otherwise complete and unworn single valves, and, in these respects, differ from usual coquinas found in the rock record. In the less densely packed fossiliferous beds associated with nearly all of these coquina beds, fossils are abundant but more widely spaced. There is much more diversity, with up to 13 species present, and articulated bivalves are common, as well as nearly complete growth series of unworn bivalves and gastropods. Seven of these fossiliferous beds were found in the restricted-coastal facies and represent the localities shown on Figures 1B, 2, and 3 as CSUN localities 1444, 1445, 1446, 1450, 1451, 1452, and 1453. Each locality overlies a coquina bed, except locality 1451, which overlies a limestone bed. There is similarity in the taxonomic composition of the fossils at these localities, but the abundance of the species varies greatly from locality to locality (Table 1).

At CSUN locality 1453, the relationship between the underlying coquina bed and the overlying fossil bed is especially clear-cut. The coquina bed consists of tightly packed and crushed specimens of *Pelecyora aequilateralis* in a sandy mudstone, and the coquina bed has a sharp contact with an overlying 10-cm-thick black mudstone containing abundant specimens of the gastropod *Tympanotonos* (*T.*) *californicus* new species These gastropods, which possess sharp spines, are complete, and specimens range from just a few millimeters to 23 mm in length. There are small patches consisting of dense concentrations of only juveniles, some of which show a slight preferred orientation.

A coquina consisting entirely of unworn and unbroken single valves of *Cuneocorbula torreyensis* directly underlies CSUN locality 1445. Some specimens are concave up, some are concave down, and a few are vertical. This coquina bed is distinctive because the specimens of the bivalves form a "shell pavement" along the bedding planes. In the immediately overlying fossiliferous silty mudstone at CSUN locality 1445, there are other mollusks in addition to abundant specimens of *C. torreyensis*. Most notable is the bivalve *Corbicula jestesi* new species Some shells of this species are articulated, and others are "butterflied," (i.e., the opposing valves are open and lying adjacent to each other on the bedding plane). Many of the specimens of *Pelecyora aequilateralis*, "*Tellina*" *joaquinensis* Arnold, 1909, and *Neotrapezium californicum* new species in the fossiliferous mudstone are articulated individuals. There are also growth series of *P. aequilateralis* and "*T.*" *joaquinensis*.

At CSUN locality 1450, a *Pelecyora aequilateralis* coquina directly underlies a fossiliferous mudstone in which many specimens of "*Tellina*" *joaquinensis, Neotrapezium californicum,* as well as *P. aequilateralis,* were found articulated. Growth series of these three bivalves and of the gastropods *Crepidula inornata* Dickerson, 1916, and *Loxotrema turritum* were also found in this fossiliferous mudstone.

Link and Welton (1982:fig. 3, section 5) reported lignite in the restricted-coastal facies and graphically depicted several lignite beds scattered throughout their measured section, which is located along the same traverse as the main measured section of this present study. I was able to find carbonaceous material (rare, very small pieces of carbonized wood), although only at CSUN locality 1445 and near the top of unit 3 in the auxiliary section. Blackish, lignitic-looking stains are associated with some of the mudstones near CSUN locality 1446, but these stains are related to postdepositional processes. The mudstone at CSUN locality 1453 is black and superficially resembles coal.

FAUNA

A total of about 1270 molluscan specimens identifiable to species were collected. Preservation of the fossils ranges from poor to moderately good, but many are in poor condition because of crushing, weathering, being coated with tightly adhering mud matrix, or a combination of all three factors. The bivalve specimens generally do not lend themselves for cleaning of the hinge, and, therefore, identification of some of the bivalves was particularly difficult. Many of the bivalves, especially "*Tellina*" *joaquinensis* and *Neotrapezium californicum,* are very fragile because the shells are particularly thin. The hinges are easily destroyed when attempts are made to remove tightly adhering mudstone.

Although I collected most of the studied specimens, I also used Jestes' (1963) collection, which is now stored at LACMIP. Diversity of the entire megafauna is low, with only 16 identifiable species, but some of the species are represented by extremely abundant specimens. Each locality has one to several dominant species, and these vary from locality to locality (Table 1).

Although Link and Welton (1982) reported turritellas and the freshwater bivalve *Unio*? from the study area, these taxa are not present. The so-called "turritellas" are the potamidid *Potamides* (*Potamidopsis*) *californica,* and the *Unio*? is *Neotrapezium californicum.*

The only other megafossils found in the restricted-coastal facies were a few, minute-sized fish scales (in mudstone at CSUN locality 1450) and rare specimens of encrusting bryozoans on oyster shells (at CSUN locality 1444).

TAPHONOMY

Both Link (1975) and Link and Welton (1982) utilized the unpublished work of Jestes (1963) in concluding that the coquinas are made up of brackish-water species that are essentially in place. Squires (1991a, 1998) studied two of the gastropod species from these coquinas and also reported them to have been brackish-water dwellers that have not undergone any significant postmortem transport.

Using the taphonomic terminology of Kidwell et al. (1986), the megafossil assemblages in the finer grained intervals represent parautochthonous assemblages. These are ones that underwent some postmortem transport but were deposited within their original habitat. The amount of postmortem transport is not the same, however, for all the mollusks in the finer grained intervals. Those at each of the seven collecting localities (Figs. 1–3) show little or no obvious evidence of any postmortem transport. They have unworn delicate sculpture, nearly complete growth series of the more abundant species, and are unbroken. There is also a high percentage of articulated and/or "butterflied" specimens, especially of *Pelecyora aequilateralis,* "*Tellina*" *joaquinensis,* and *Neotrapezium californicum.* These assemblages are closely analogous to paleocommunities, but they cannot be referred to as such because no specimens were found in life position. According to Kidwell et al. (1986), paleocommunities (autochthonous assemblages) are composed of specimens preserved in life position. Evidently, the megafossils found at each of the seven collecting localities experienced postmortem transport of a very short distance. At CSUN locality 1453, there is, in fact, some evidence of postmortem transport where localized concentrations of only juvenile *Tympanotonos* (*T.*) *californicus* are found. They show a low degree of preferred orientation. It is not uncommon to find adult shells lying next to each other, with their apices pointing in opposite directions. This is commonly associated with wave sorting of shells, but the amount of postmortem transport must have been slight because the very delicate apical tips are present on many specimens, and sharp projecting nodes are present on nearly every specimen. These localized concentrations grade into mudstone, containing other mollusks that show no obvious signs of postmortem transport.

Burial of all the mollusks must have been rapid because the shells show no clionid sponge boreholes, algal boreholes, or corrosion and only rare cases of epifaunal incrustations by bryozoans. The only boreholes found were on rare specimens of *Tympanotonos* (*T.*) *californicus, Pelecyora aequilateralis,* and "*Tellina*" *joaquinensis.* These boreholes most likely were made by the carnivorous gastropods *Crommium* sp. cf. *C. andersoni* (Dickerson, 1914) and *Neverita* (*N.*) *globosa* Gabb, 1869.

The fossils in the muddy coquinalike beds, which usually directly underlie the seven main collecting

localities, were more affected by postmortem transport, as evidenced by their concentration in large numbers of essentially one species (e.g., *Pelecyora aequilateralis* or *Cuneocorbula torreyensis*). Nevertheless, postmortem transport was within the original environment, based on the unworn and unbroken condition of the specimens and the presence of these same species in the immediately overlying assemblages that show little or no obvious signs of postmortem transport.

Using the taphonomic terminology of Kidwell et al. (1986), the fossils in the sandstones represent allochthonous assemblages transported out of their original habitat. These fossils consist only of scattered fragments of the oyster *Acutostrea idriaensis idriaensis* that were transported out of their nearby original muddy environment (see discussion below) and deposited in sand, which represented a foreign substratum. Their transported condition is based on their fragmented condition (mostly small-sized fragments). Only in the lower part of unit 3 in the main measured section are the fragments abundant enough to form an oyster hash. The source of the oysters was local, based on the presence of unworn, large single valves (up to 80 mm long) and a few articulated specimens of the oysters in the subjacent finer grained intervals. When the oysters were transported, they survived the high-energy processes to some degree because of their stout shells.

DEPOSITIONAL ENVIRONMENT

In the region surrounding the study area, the Matilija Sandstone consists of deep-marine to shallow-marine deltaic facies associated with a major regressive event. In the lower part of the formation, sand-rich proximal turbidite deposition took place in outer neritic, bathyal depths, or both on the flanks of a prograding delta. As the delta prograded and filled the basin, the turbidites were covered by shallow-marine shelf deposits that grade upward into the restricted-coastal deposits, which formed at the delta top. These latter deposits are overlain, in turn, by shallow-marine shelf deposits that make up the uppermost part of the Matilija Sandstone. These uppermost beds are transitional with the deep-water Cozy Dell Shale and record a rapid basin deepening (Link, 1975; Link and Welton, 1982).

Link (1975) reported that the finer grained intervals in the restricted-coastal facies represent a low-energy lagoonal, bay, or estuarine environment. He also reported that the interbedded limestone and gypsum, in association with mudcracks and red beds suggest very shallow, quiet-water deposition in a high-evaporation environment. Furthermore, he reported that the sandstones formed in much higher energy conditions associated with narrow beaches or tidal channels. Link and Welton (1982) and Squires (in press) refined these interpretations and reported that the mudstone and coquina in the finer grained intervals represent a low-energy, lagoonal environment where brackish-marine mollusks lived, and that the limestone, evaporites, and "red beds" formed in a sabkha environment along the margin of the lagoon. The "red beds" probably indicate subaerial exposure, and furthermore the well-sorted, horizonally laminated, very fine to fine-grained sandstones represent beach and barrier-bar washover deposits brought by storms into the lagoon. The limestone to gypsum evaporite sequences represent increasingly hypersaline conditions along the shoreline of the lagoon, and the complex alterations of these lithologies indicate rapidly fluctuating conditions. Squires (1998) reported that the formation of these evaporites coincided with a regional change of climate from humid subtropical or tropical to seasonal semiarid conditions.

The megafauna in the restricted-coastal rocks at Matilija Hot Springs is strongly indicative of brackish-water conditions. Some of the species are known elsewhere only from brackish-marine rocks and include: *Potamides* (*Potamidopsis*) *californica, Loxotrema turritum, Pyrgulifera* (*P.*) *lajollaensis* (Hanna, 1927), *Pelecyora aequilateralis, Cuneocorbula torreyensis,* and "*Tellina*" *joaquinensis*. Each of these species is discussed below.

Potamides (*Potamidopsis*) *californica* has been found elsewhere only in brackish-marine rocks in the Matilija Sandstone at Beartrap Creek of the Pine Mountain area, Ventura County, southern California (Squires, 1991a). The paleoenvironment of this species is consistent with modern analogues. Today, potamidids feed on surface detritus that accumulates on mud surfaces of enclosed intertidal flats in warm waters (Morton and Morton, 1983).

Loxotrema turritum is widespread and ranges from southern California to northwestern Kamchatka, Russia. Nearly all of the northeastern Pacific early Eocene specimens of this species underwent downslope postmortem transport, most likely from deltaic areas, into deeper waters and became mixed with shallow-marine mollusks. The northeastern Pacific middle Eocene specimens of this species lived in brackish-marine lagoons or bays within deltaic complexes (Squires, 1998). The northwestern Kamchatka middle Eocene specimens are found in coastal-marine rocks (Devyatilova and Volobueva, 1981).

Pyrgulifera (*P.*) *lajollaensis* is present in brackish-marine rocks in San Diego County, southern California (Hanna, 1927; Givens and Kennedy, 1979). In modern usage, these rocks are referred to as the Delmar Formation. This species is also known from one locality (UCR loc. 4747) in the Matilija Sandstone at Beartrap Creek (Givens, 1974). At this locality, the species is associated with *Loxotrema turritum, Potamides* (*P.?*) *carbonicola* Cooper, 1894, and the gastropod *Nerita* (*Theliostyla*) *triangulata* Gabb, 1869, as well as with the bivalve *Acutostrea idriaensis idriaensis*. These latter two species are common constituents of northeastern Pacific brackish-marine and very shallow-marine Eocene molluscan faunas (e.g., Vokes, 1939; Squires, 1984;

Squires, 1992). *Pyrgulifera,* long believed to be a freshwater genus, was reported by Bandel and Riedel (1994) to be a brackish-water genus that could tolerate freshwater inflow.

Pelecyora aequilateralis and *Cuneocorbula torreyensis* have been found elsewhere in three formations. One is the brackish-marine Delmar Formation near San Diego (Hanna, 1927; Givens and Kennedy, 1979). The second is a brackish-marine part of the Domengine Sandstone in the Vallecitos syncline near New Idria in central California, and some of these rocks contain *Loxotrema turritum* and *Potamides* (*P.*?) *carbonicola,* as well as some coal beds (Vokes, 1939). The third is a section of rocks referred to by modern workers as the Whitetail Ridge Formation near Glide in southwestern Oregon (Turner, 1938; Niem et al., 1992). Utilizing the work of Niem et al. (1992), Squires (1998) assigned these latter rocks to a deltaic (mixed fluvial and shallow marine) origin. *Cuneocorbula torreyensis* is also recorded from "Transition" age brackish-marine strata in the upper Juncal Formation in the Pine Mountain area in southern California (Givens, 1974).

"*Tellina*" *joaquinensis* has been found elsewhere with certainty only in localized brackish-marine rocks in Coalmine Canyon near Coalinga, central California (Arnold, 1909; Arnold and Anderson, 1910; Vokes, 1939). In modern usage, these rocks are referred to as the Domengine Formation. Two of the associated species in the Coalmine Canyon rocks are *Loxotrema turritum* and *Potamides* (*P.*?) *carbonicola.*

Crommium andersoni, which is most likely present at Matilija Hot Springs, as well as *Neverita* (*N.*) *globosa, Acutostrea idriaensis idriaensis,* and *Barbatia* (*B.*) *morsei* Gabb, 1864, which are all present at Matilija Hot Springs, are similar in that they all have been found in brackish-marine strata, as well as in shallow-marine environments (Arnold, 1909; Vokes, 1939; Givens, 1974; Givens and Kennedy, 1976, 1979; Squires, 1987; Nesbitt, 1995). These species, which appear to have been euryhaline, indicate that the muddy and silty environs in the restricted-coastal facies probably had some connection to the open ocean. Nesbitt (1995) reported an *Acutostrea idriaensis idriaensis* paleocommunity from the upper middle Eocene Cowlitz Formation of southwestern Washington, and she inferred that this oyster "inhabited a shallow-water, soft-bottom embayment of a delta shore in which the water temperatures and salinites were seasonally very variable."

The gastropod *Crepidula inornata* and the bivalve "*Tellina*" *domenginensis* Vokes, 1939, are the only mollusks in the restricted-coastal facies at Matilija Hot Springs that have not been previously found in brackish-marine deposits. Possibly displaced (brackish-marine?) specimens of *C. inornata,* however, have been found in rocky shoreline deposits in the basal part of the Tejon Formation at the Edmonston Pumping Plant, Tehachapi Mountains, south-central California (Lindberg and Squires, 1990). The numerous and well-preserved juvenile through adult, growth-stage specimens of this gastropod at Matilija Hot Springs strongly indicate that this species inhabited the brackish-marine environment. Like modern analogues, *C. inornata* would have been a hard-substrate-dwelling gastropod with a sedentary, epifaunal suspension (filter) feeding mode of life. Most *Crepidula* spp. are generalists with respect to temperature and salinity, and this has allowed them to be stable species in unstable environments (Hoagland, 1977), which would be the norm for brackish-marine conditions.

"*Melanatria*" *markleyensis* (Clark, 1938) was known previously only from the northeastern Pacific region at a single locality in the Markley Formation in northern California. This locality contains mostly shallow-marine mollusks in coarse-grained sandstone with lenses of conglomerate, but Clark (1938) reported that the megafauna has a brackish-water element, as shown by "*Melanatria*" *markleyensis* and species belonging to *Corbicula* and the gastropod *Elimia.* In the northwestern Kamchatka area, "*M.*" *markleyensis* has been found in middle Eocene coastal-marine rocks (Devyatilova and Volobueva, 1981). Today, *Melanatria* is found in rivers and streams in Madagascar (Starmühlner, 1969; Brown, 1980). The presence of "*M.*" *markleyensis* at the Matilija Hot Springs section could be explained in two ways: During the Eocene, either this species was a brackish-water dweller, or the specimens in the section were transported there from nearby freshwater sources. The former seems more likely because the specimens are unabraded.

The three new species found in the restricted-coastal facies at Matilija Hot Springs belong to genera that can be present in brackish-marine conditions. *Tympanotonos* is moderately common in Eocene and lower Oligocene strata of France, and Gitton et al. (1986) reported the genus from lower Oligocene lagoonal-marine strata in the Paris basin. The genus is found today in coastal-marine mangrove swamps (Bouchet, 1977; Plaziat, 1977). Modern species of *Neotrapezium* are commonly found attached by their byssus to hard substrates, and at least a few species (such as *Neotrapezium liratum;* Reeve, 1843) live in warm waters of low salinity (Kira, 1965; Morton, 1979; Morton and Morton, 1983). *Neotrapezium californicum* might have lived attached to the oyster *Acutostrea idriaensis idriaensis.* The byssate epifaunal bivalve *Barbatia* (*B.*) *morsei* and hard-substrate-dwelling gastropod *Crepidula inornata* could have done likewise.

Although fossil forms of *Corbicula* are found in brackish-marine, freshwater, and shallow-marine strata, modern forms are found only in brackish-marine and freshwater environments (Keen and Casey, 1969).

The depositional scenario of the restricted-coastal facies of the Matilija Sandstone at Matilija Hot

Springs agrees closely with what has been observed in modern lagoons that form behind barriers. As summarized by Boggs (1987), modern lagoons are typically low-energy environments, although tidal currents move into the lagoons through inlets between barriers, winds create some wind action along shorelines, and storms provide occasional periods of high-energy waves that can bring in washover deposits from the barrier beach. Interbedded sands are generally horizontally laminated. Faunas are highly variable and generally characterized by low diversity. The salinity conditions largely dictate the taxonomic composition of the faunas. Lagoons with normal salinity show faunas similar to those of the open ocean, whereas brackish-marine faunas dominate more restricted lagoons (Boggs, 1987). Huge numbers of specimens are commonly associated with these brackish-marine conditions (Bandel and Riedel, 1994). Carbonate deposition can prevail if somewhat hypersaline conditions are present, and if these conditions become very arid, then evaporites (mainly gypsum) form. Very hypersaline lagoons contain few organisms (Boggs, 1987).

AGE

Link and Welton (1982) reported a middle Eocene (P11 and P12 Zones of the standard planktonic zonation) age for the overlying Cozy Dell Formation in the Matilija Hot Springs area. The P11 Zone is equivalent to the CP13b and CP13c Zones of the standard calcareous nannoplankton zonation (Berggren et al., 1995). The restricted-coastal facies, therefore, are no younger than the CP13b or CP13c Zones. Squires (in press) assigned the restricted-coastal facies to the lower middle Eocene "Transition Stage," which is equivalent to the CP13a Zone.

SYSTEMATIC MATERIALS AND METHODS

Systematic arrangement of higher taxa of the gastropods generally follows Ponder and Warén (1988), and that of the bivalves follows Vokes (1980) and Coan and Scott (1997). The synonymies are selective. Usually, only works that include illustrations of the species are listed. In a few cases, however, works that only have faunal lists are included if they add significant geographic information about a species. The figured specimens used in this report, as well as the material collected by Jestes (1963), are on deposit in the Natural History Museum of Los Angeles County, Invertebrate Paleontology Section. Additional unfigured specimens are on deposit in the Department of Geological Sciences Paleontology collection, California State University, Northridge.

SYSTEMATICS

Class Gastropoda Cuvier, 1797

Superorder Caenogastropoda Cox, 1959

Order Neotaenioglossa Haller, 1882

Superfamily Cerithioidea Férussac, 1819

Family Potamididae Adams and Adams, 1854

Genus *Potamides* Brongniart, 1810

TYPE SPECIES. *Potamides lamarcki* Brongniart, 1810, by monotypy; Oligocene, St. Michiel, France.

Subgenus *Potamidopsis* Munier-Chalmas, 1900

TYPE SPECIES. *Cerithium tricarinatus* Lamarck, 1804, by original designation; middle Eocene, Paris Basin, France.

Potamides (*Potamidopsis*) *californica* Squires, 1991a

Figures 4, 5

Potamides sp. Jestes, 1963:223.

Potamides aff. *P. tricarinata* (Lamarck). Jestes, 1963:225.

Potamides (*Potamidopsis*) *californica* Squires, 1991a:356–358, figs. 2–5.

PRIMARY TYPE MATERIAL. LACMIP holotype 11300, LACMIP paratypes 11301, 11302; all from the Matilija Sandstone, Beartrap Creek, Pine Mountain area, Ventura County, southern California, LACMIP loc. 7226.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12440–12441.

MOLLUSCAN STAGE RANGE. "Transition" to lower part of "Tejon."

GEOGRAPHIC DISTRIBUTION. Matilija Hot Springs and Beartrap Creek, Ventura County, southern California.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1453.

REMARKS. This is the most ubiquitous gastropod in the restricted-coastal facies and is very abun-

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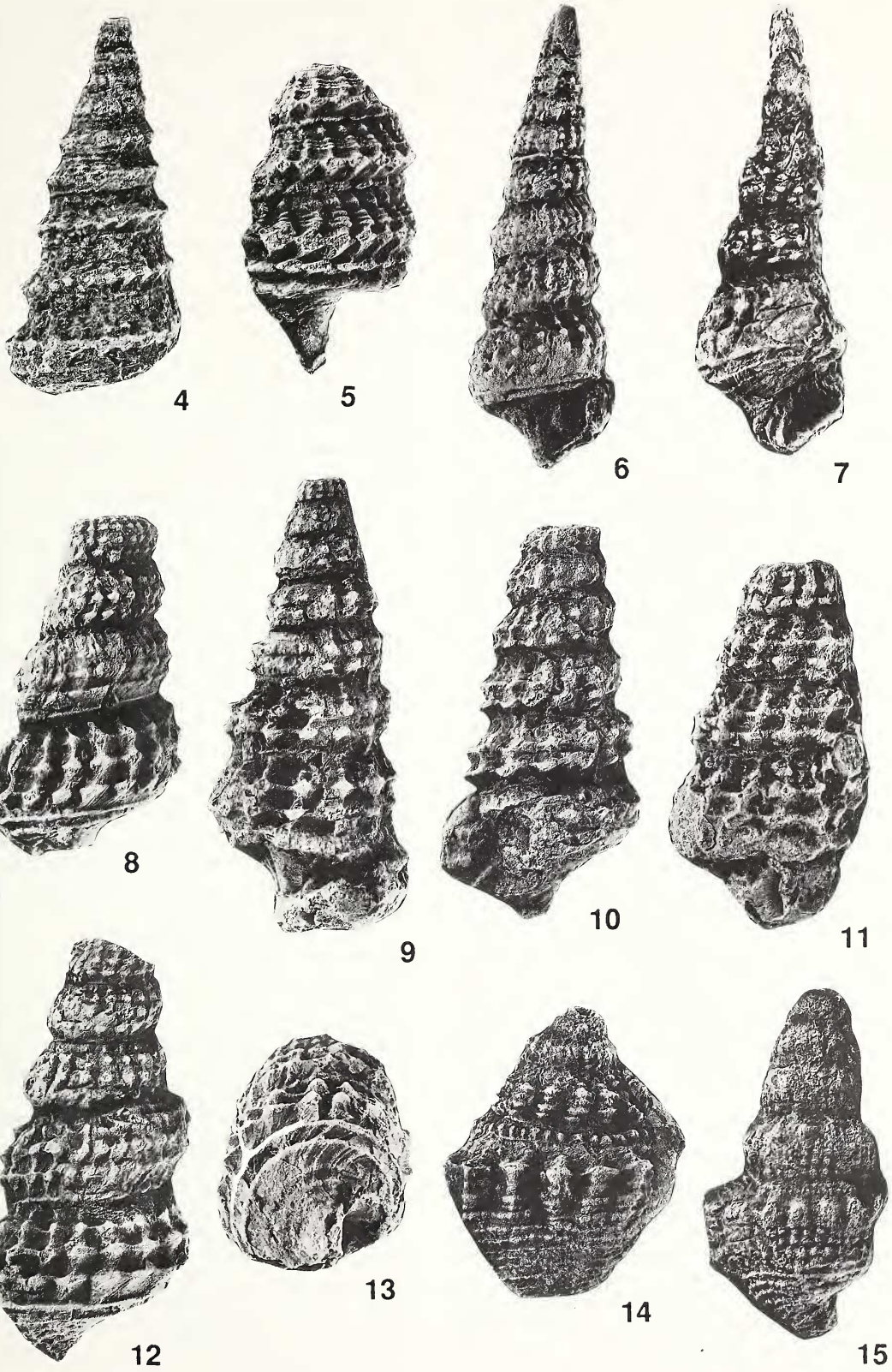
Figures 4–15. Gastropods from Matilija Hot Springs area upper part of the Matilija Sandstone. CSUN loc. 1453 unless otherwise indicated. All specimens coated with ammonium chloride. 4, 5. *Potamides* (*Potamidopsis*) *californica* Squires, 1991. 4. Abapertural view, ×2.5, LACMIP hypotype 12440. 5. Apertural view, ×2.6, LACMIP hypotype 12441. 6–13. *Tympanotonos* (*T.*) *californicus* new species. 6. Apertural view, ×3.9, LACMIP paratype 12443. 7. Apertural view, ×3.5, LACMIP paratype 12444. 8. Abapertural view, ×3.8, LACMIP paratype 12445. 9. Apertural view, ×3.7, LACMIP holotype 12442. 10. Abapertural view, x 3, LACMIP paratype 12446. 11. Apertural view, ×3.6, LACMIP paratype 12447. 12, 13. LACMIP paratype 12448. 12. Abapertural view, x 3. 13. Oblique view of partial left side and anterior end, ×3. 14. *Pyrgulifera* (*P.*) *lajollaensis* (Hanna, 1927), abapertural view, ×2.4, LACMIP hypotype 12449, CSUN loc. 1445. 15. "*Melanatria*" *markleyensis* (Clark, 1938), abapertural view, ×3.9, LACMIP hypotype 12450, CSUN loc. 1445.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dant at localities 1444 and 1450. At the other localities, between six and 12 specimens were found. Specimens are usually encased in brittle mudstone or silty mudstone, and extraction from the outcrop almost always results in loss of the uppermost spire and the aperture. Although no complete specimens were found, a few nearly complete specimens (up to 32 mm high) were recovered. This species is characterized by a turritelliform shape, concave whorls with reticulate sculpture, and a noded carina near the anterior suture. A sutural spiral rib immediately posterior to the suture can be strong on some specimens, such as the exceptionally well-preserved specimen illustrated in Figure 5. This same specimen also shows that the anterior half of the body whorl has three spiral ribs, all of which are noded. None of the specimens at any of the localities shows evidence of postmortem transport. The nodes on the carina are always sharp and unworn.

Potamidopsis is known only from upper Paleocene and middle Eocene brackish-marine strata in France and lower middle Eocene brackish-marine strata in southern California (Squires, 1991a). Saul and Squires (1998) reported a possible Early Cretaceous (Hauterivian Stage) species of *Potamidopsis* from the Ogo Member of the Budden Canyon Formation along the North Fork Cottonwood Creek, Shasta County, northern California. To date, *Potamides* (*Potamidopsis*) *californica* is known only from the Matilija Sandstone in Ventura County, southern California.

Genus *Tympanotonos* Schumacher, 1817

TYPE SPECIES. *Tympanotonos fluviatilis* Schumacher, 1817 [= *Murex fuscatus* Linnaeus, 1758], by monotypy; Recent, West Africa.

Subgenus *Tympanotonos* s.s.

Tympanotonos (*Tympanotonos*) *californicus* new species
Figures 6–13

DIAGNOSIS. A *Tympanotonos* s.s. in which the upper spire has rounded whorls with three equal spiral ribs showing small nodes and the lower spire has angulate whorls with cancellate sculpture consisting of two to three spiral ribs and numerous axial ribs.

COMPARISON. *Tympanotonos* (*T.*) *californicus* new species is most similar to *T.* (*T.*) *fuscatus radula,* which lives today in mangroves along the coast of West Africa. Some earlier workers, such as Thiele (1929–1935) considered *T.* (*T.*) *fuscatus radula* to be a distinct species, but modern workers such as Plaziat (1977) consider it a variety of *T.* (*T.*) *fuscatus*. Plaziat (1977) found both in the same general brackish-water habitat but reported that *radula* lives higher than *fuscatus* in the estuarine and deltaic mangrove swamps near Douala in Cameroon, Africa. A specimen of *T.* (*T.*) *radula* illustrated by Thiele (1929:fig. 202) and specimens of *T.* (*T.*) *fuscatus radula* illustrated by Plaziat (1977:figs. 6a–6b, 7a–7c) are useful for comparative purposes with the new species, which differs by having slightly more rounded whorls on the lower spire. The new species is similar in the upper spire sculpture to *T.* (*T.*) *fuscatus fuscatus* from Liberia, Africa [LACM lot 51–4], but the new species differs by having much more subdued sculpture on the rest of the shell rather than having the large and projecting spines that characterize the carinate shoulder of the lower spire and body whorl of *T.* (*T.*) *fuscatus fuscatus*.

DESCRIPTION. Medium in size, up to 23 mm high (estimated), turreted-conical, approximately 15 whorls; high-spired with spire about two-thirds of shell height. Suture impressed, immediately anterior to a spiral riblet. Protoconch missing, apical area rapidly tapering (acicular), pleural angle approximately 20°. Whorl convexity changes with growth; earlier spire whorls rounded and gradational into angulate whorls on more mature spire and body whorl. Teleoconch sculpture consisting of spiral ribs crossed by numerous axial ribs. Sculpture changes with growth. Upper spire with three equal spiral ribs; beaded to noded where crossed by axial ribs. On middle and lower spires, posterior-most spiral rib weakens, with the other two spiral ribs becoming carinate, more strongly noded, and more prominent with growth. Sculpture cancellate with nodes projected somewhat; interareas between the two rows of nodes rather deep. On rare specimens, weak posterior-most spiral rib obsolete or nearly so. Mature whorls of very rare specimens with a fourth spiral rib, moderately prominent and noded, near the anterior suture. Posterior half of body whorl with three spiral ribs bearing strong nodes; posterior-most spiral rib weakest. Anterior half of body whorl flattish, with approximately six unnoded spiral ribs, strength decreasing anteriorly. Aperture somewhat roundish; inner lip smooth and twisted. Anterior end of aperture with a narrow but distinct notch. Outer lip not seen.

HOLOTYPE DIMENSIONS. 18.9 mm high, 7.5 mm wide.

PRIMARY TYPE MATERIAL. LACMIP holotype 12442 (illustrated), LACMIP paratypes 12443 to 12448 (all illustrated); all from CSUN loc. 1453.

TYPE LOCALITY. CSUN loc. 1453.

MOLLUSCAN STAGE RANGE. "Transition."

GEOGRAPHIC DISTRIBUTION. Matilija Hot Springs, southern California.

LOCAL OCCURRENCE. CSUN locs. 1444, 1450, 1451, 1453.

REMARKS. The new species is most abundant at CSUN locality 1453, where it forms coquinas. It is common at the other localities. Specimens range from 5 to 25 mm in height. Whether or not the largest specimens found represent fully mature individuals cannot be resolved, but it seems unlikely. On the bedding planes of some hand-specimens of rock, there are densely packed patches of mostly same-sized specimens less than 10 mm high. These

patches represent concentrations of juvenile specimens. These small specimens have rounded whorls with beaded sculpture on three equal spiral ribs and could easily be mistakenly identified as a separate species if more mature specimens (e.g., Figs. 8, 9, 12) showing a transition from rounded whorls with beaded sculpture to angulate whorls with cancellate sculpture were not present. It is uncommon to find specimens that show this transition in sculpture because nearly all the more mature specimens are missing their tips. This might be the result of breakage that occurred either during postmortem transport or during removal of the larger specimens from the rock. The mudstone containing the specimens of the new species is brittle and highly fractured. It easily falls apart, and removal of the larger specimens is extremely difficult. In addition, no specimens of the new species were found that show the outer lip, and only rare specimens show the outline of the aperture. Most likely these features were either crushed by postburial compaction or broken off when the rock was split to initially reveal the specimens. It is also possible that, at least in some cases, the more delicate parts of the shells were broken off prior to burial.

Wenz (1939) reported the geologic range of *Tympanotonos* to be Late Cretaceous (Turonian) to Recent. During the Eocene, the genus was relatively diverse in France, especially in the Paris Basin (Cossmann and Pissarro, 1910–1913; Le Renard and Pacaud, 1995). The French species belong to either subgenus *Eotympanotonus* Chavan, 1952, or to subgenus *Diptychochilus* Cossmann in Doncieux, 1908. The former is characterized by whorls whose posterior-most spiral rib develops spines, whereas the latter has a smooth but tabulate carina on the shoulder of the whorls. Neither subgenus is characterized by cancellate sculpture such as that seen on the new species.

The new species, which belongs to *Tympanotonos* s.s., is the only confirmed record of *Tympanotonos* in North America. Flynn et al. (1989:fig. 3 [1a–1b]) reported *Tympanotonos* sp. aff. *T. papalis* from lower Eocene ("Capay Stage") strata of the Bateque? Formation near the village of "El Rosario" [i.e., Rosarito] in Baja California Sur, Mexico. Squires and Demetrion (1992), however, reported that the northernmost exposures of the Bateque Formation are far south of the area studied by Flynn et al. (1989). The specimens of the so-called *Tympanotonos* sp. aff. *T. papalis* from the Rosarito area lack apertures and upper spires. These specimens are quite unlike those of *T.* (*Eotympanotonus*) *papalis* (Deshayes, 1833; Cossmann and Pissarro, 1910–1913:pl. 29, fig. 151bis–5), known from lower Eocene (Cuisian Stage) strata of the Paris Basin, France. The Mexican specimens have a lowly noded carina on the shoulder of the whorls, and the remaining parts of the whorls are smooth. The Mexican specimens are somewhat similar to Paris Basin species of *Tympanotonos (Eotympanotonus)*, as well to certain species of the cerithiid genus *Seratocerithium* Vignal, 1897, but positive identification of the Mexican specimens awaits better preserved material.

ETYMOLOGY. The species is named for the state of California.

Genus *Pyrgulifera* Meek, 1877

TYPE SPECIES. *Pyrgulifera humerosa* Meek, 1877, by monotypy; Upper Cretaceous (Cenomanian), Bear River Formation, near Bear River, southwestern Wyoming.

Subgenus *Pyrgulifera* s.s.
Pyrgulifera (*Pyrgulifera*) *lajollaensis* (Hanna, 1927)
Figure 14

Trichotropis (?) *lajollaensis* Hanna, 1927:311–312, pl. 48, figs. 4–6, 9, 11.
Trichotropsis? *lajollaensis* Hanna. Clark, 1929:pl. 10, fig. 12.
Trichotropis(?) sp. Jestes, 1963:226.
"*Trichotropis*" *lajollaensis* Hanna. Givens, 1974: 70, pl. 6, fig. 18.
Gyrineum (?) sp. Jestes, 1963:226.
Pyrgulifera lajollaensis (Hanna). Givens and Kennedy, 1979:95, table 2.

PRIMARY TYPE MATERIAL. UCMP holotype 30906, UCMP loc. 3992; UCMP paratype 30907, UCMP loc. 5084; UCMP paratype 30908, UCMP loc. 3992; all from the Delmar Formation, south of Del Mar, San Diego County, southern California.

ILLUSTRATED SPECIMENS. LACMIP hypotype 12449.

MOLLUSCAN STAGE RANGE. "Domengine" to lower part of "Tejon."

GEOGRAPHIC DISTRIBUTION. San Diego and Matilija Hot Springs, southern California.

LOCAL OCCURRENCE. CSUN locs. 1445, 1446, 1450, 1452, 1453.

REMARKS. A total of 21 specimens were found. Eight were found at locality 1450, and they range from 13 to 28 mm in height. Seven specimens were found at locality 1445, and they range from 18 to 25 mm in height. At the other localities, only two or three specimens were found. Nearly all the collected specimens are poorly preserved. Some are only internal molds.

This species is characterized by a short, stout shell with angulate whorls, a wide ramp, numerous pointed axial nodes, and strong spiral ribs covering the entire shell. The axial nodes on the Matilija Hot Springs specimens are sharp and unworn, thereby indicating no signs of postmortem transport.

The familial assignment of *Pyrgulifera* is tenuous. Traditionally, it has been assigned to family Thiaridae, but Bandel and Riedel (1994) recently placed it in family Potamididae. Wenz (1939) reported that the geologic range of *Pyrgulifera* is Late Cretaceous (Cenomanian) to Eocene. Two species are known from estuarine rocks in the Upper Cre-

taceous (Cenomanian) Bear River Formation in southwestern Wyoming (White, 1895; Yen, 1954, 1958). Stephenson (1952) described two species of *Pyrgulifera* from the Cenomanian Woodbine Formation of Texas, but Bandel and Riedel (1994) considered the generic identification as doubtful. One of these Woodbine Formation species, *Pyrgulifera ornata* Stephenson (1952:157–158, pl. 37, figs. 9–13), however, does look much like a *Pyrgulifera.*

Givens (1974:70) reported *Pyrgulifera lajollaensis* from the *Ectinochilus canalifer* megafaunal biozone of the Matilija Sandstone at Beartrap Creek of the Pine Mountain area, Ventura County, southern California. Squires (in press) reported that the Matilija Sandstone in the Beartrap Creek area is early middle Eocene in age and equivalent to the lower part of the "Tejon Stage."

Family Thiaridae Troschel, 1857

Genus *Melanatria* Bowdich, 1822

TYPE SPECIES. *Buccinum flumineum* Gmelin in Linnaeus, 1767, by original designation?; Recent, Madagascar, rivers and streams.

"*Melanatria*" *markleyensis* (Clark, 1938)
Figures 15–17

Thiara (*Melanoides*) *markleyensis* Clark, 1938: 706, pl. 3, figs. 24, 30; table 1.
Cerithium sp. Jestes, 1963:222.
Bittium (?) *dumblei* (Dickerson). Jestes, 1963:226.
Melania markleyensis (Clark). Devyatilova and Volobueva, 1981:114, pl. 9, figs. 16–18.

PRIMARY TYPE MATERIAL. UCMP holotype 30891; UCMP paratype 30892; both from the Markley Formation near Vacaville, Solano County, northern California, UCMP loc. A1297.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12450 and 12451.

MOLLUSCAN STAGE RANGE. "Transition" to "Tejon."

GEOGRAPHIC DISTRIBUTION. Matilija Hot Springs, southern California; Pleasant Creek near Vacaville, northern California; and northwestern Kamchatka, Russia.

LOCAL OCCURRENCE. CSUN locs. 1445, 1446.

REMARKS. A total of 45 specimens were found, and 30 of these are from locality 1445. Although most specimens from locality 1445 are fragments, usually consisting of just the apices, a few represent nearly complete specimens that range from 11 to 26.5 mm in height. Jestes, who must have picked up weathered-out material, collected these fragmentary specimens. I collected specimens from this same locality by removing rock from the outcrop, and these specimens are mostly complete, although the apertures are always poorly preserved. Only five specimens of this species were found at CSUN locality 1446. Two consist of moderately large fragments, and the other three are weathered tips.

The specimen that best shows the aperture is illustrated in Figure 16, but the outer lip and anterior end of the aperture are missing. This species is characterized by tabulate whorls on most of the spire and body whorl, by prominent axial nodes a short distance below the suture, and by beaded spiral sculpture. The apertural features are poorly known for this species, but the anterior end appears to be unnotched. Strength of the axial nodes is variable, as is their extent along the sides of the whorls.

I use quotation marks for the generic assignment of Clark's (1938) species, which cannot be assigned with certainty to any genus because apertural details are not fully known. I tentatively assign Clark's species to *Melanatria* rather than to *Thiara* Bolton in Röding, 1798 [= *Melania* Lamarck, 1799 fide Wenz (1939)], or *Melanoides* Olivier, 1804, because the species has more morphologic similarity to the type species of *Melanatria* than to the type species of the other two genera. Similar to *Melanatria fluminea,* which is the type species of *Melanatria,* Clark's species has a turreted-conical shape, whorls bearing prominent spiral ornament and axial ribs, and an apparently unnotched aperture. Although the type species of *Thiara,* which is *Thiara* (*T.*) *amarula* (Linnaeus, 1758), is somewhat similar to Clark's species, *T.* (*T.*) *amarula* has an oval-turreted shape, a row of backward-directed spines on the body whorl shoulder, smooth or fine spiral ornament, and a feebly notched anterior end of the aperture (Davies and Eames, 1971). The type species of *Melanoides,* which is *M.* (*M.*) *tuberculata* (Müller, 1774), differs significantly from Clark's species by having a fusiform shape, rounded whorls, and cancellate sculpture (especially on the spire).

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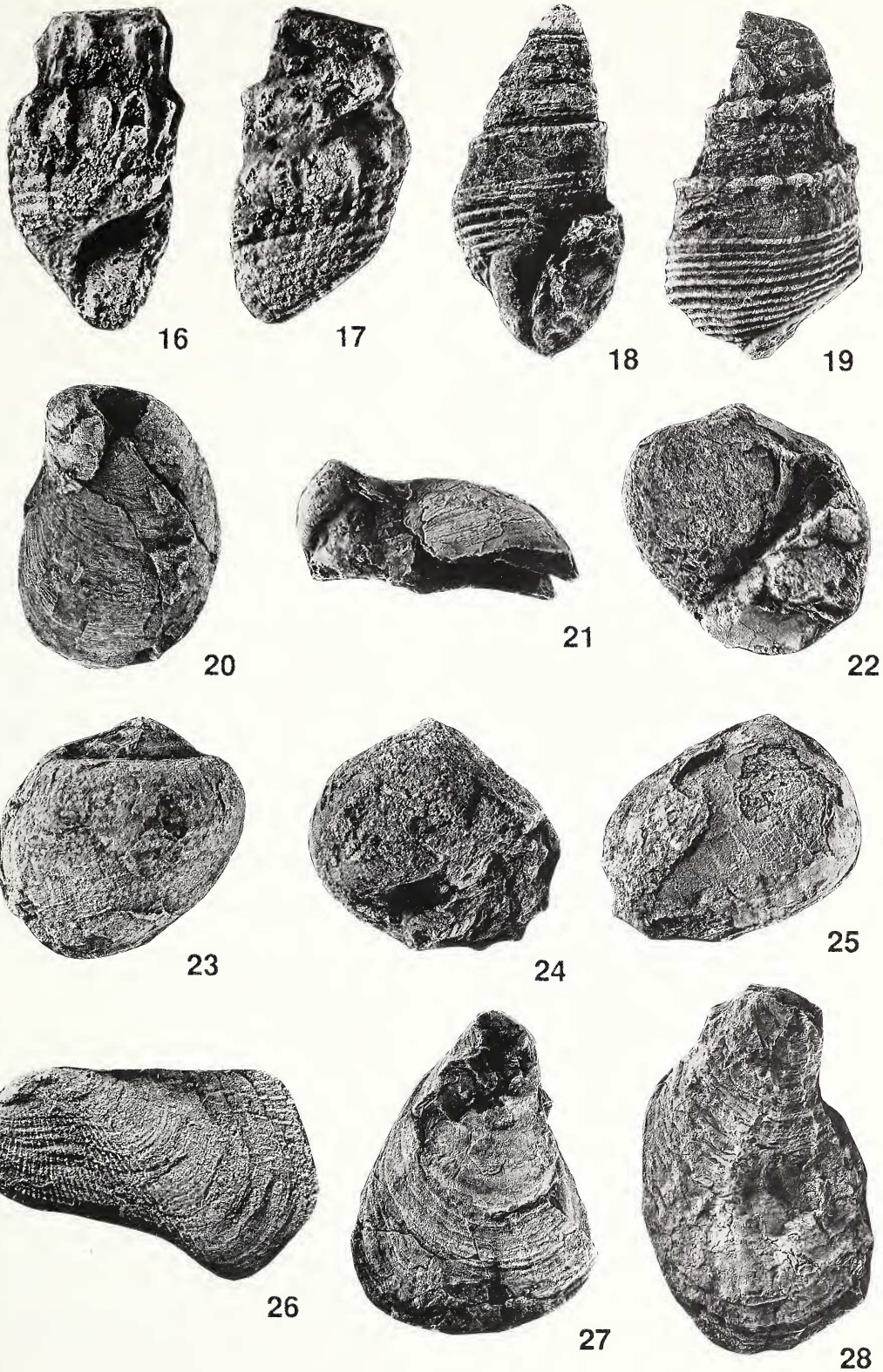
Figures 16–28. Gastropods and bivalves from Matilija Hot Springs area upper part of the Matilija Sandstone. CSUN loc. 1450 unless otherwise indicated. All specimens coated with ammonium chloride. **16–26.** Gastropods. **16, 17.** "*Melanatria*" *markleyensis* (Clark, 1938), ×5.2, LACMIP hypotype 12451, CSUN loc. 1445. **16.** Apertural view. **17.** Abapertural view. **18, 19.** *Loxotrema turritum* Gabb, 1868. **18.** Apertural view, ×1.8, LACMIP hypotype 12452. **19.** Abapertural view, ×2.6, LACMIP hypotype 6451, CSUN loc. 1446. **20, 21.** *Crepidula inornata* Dickerson, 1916, ×2.3, LACMIP hypotype 12453. **20.** Dorsal view. **21.** Right-side view. **22, 23.** *Crommium* sp. cf. *C. andersoni* (Dickerson, 1914), ×2.6, LACMIP hypotype 12454. **22.** Apertural view. **23.** Abapertural view. **24, 25.** *Neverita* (*Neverita*) *globosa* Gabb, 1869, ×2.8, LACMIP hypotype 12455. **24.** Apertural view. **25.** Abapertural view. **26–28.** Bivalves. **26.** *Barbatia* (*Barbatia*) *morsei* Gabb, 1864, left valve, ×4.8, LACMIP hypotype 12456. **27, 28.** *Acutostrea idriaensis idriaensis* (Gabb, 1869). **27.** Left valve, ×1.7, LACMIP hypotype 12457. **28.** Left valve, ×1.4, LACMIP hypotype 12458.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"*Melanatria*" *markleyensis* resembles *Thiara* (*Melanoides*) *calafi* Clark (1938:706, pl. 3, figs. 24, 30). Both are from the same bed in the upper Eocene Markley Formation in northern California. "*Melanatria*" *markleyensis* differs from *T.* (*M.*) *calafi* by having whorls with a much stronger tabulate shoulder, coarser and fewer nodes on the shoulder, much closer proximity between the shoulder and the suture, and better development of beaded sculpture on the spiral ribs on the whorls. Clark (1938) reported that both of his species are closely related to *Potamides fettkei* Weaver (1912:36, pl. 2, figs. 23, 24; 1942 [1943]:379–380, pl. 75, figs. 18, 21, 22, 26) from the upper middle Eocene Cowlitz Formation in southwestern Washington. Givens and Kennedy (1976:964) reassigned "*Potamides*" *fettkei* to genus *Melanoides*. Although "*Melanatria*" *markleyensis* resembles *Melanoides fettkei,* especially in the prominent nodes on the shoulder, *T.* (*M.*) *calafi* is more like *Melanoides fettkei.* "*Melanatria*" *markleyensis* differs from *Melanoides fettkei* by having a much closer proximity of the tabulate shoulder and the suture, more closely spaced nodes on the shoulder, coarser beaded sculpture on the spiral ribs on the whorls, and no secondary spiral ribs.

Houbrick (1991) assigned *Melanatria* to the family Thiaridae. On the basis of a shared unique and unusual foliate gastric structure, he implied that the phylogenetic placement of *Melanatria* is close to the genera *Faunus* Montfort, 1810, and *Melanopsis* Férussac, 1807. He also reported that more work is needed to clarify their phylogenetic relationships.

Devyatilova and Volobueva (1981) reported this species from coastal-marine rocks of the middle Eocene Kamchik Formation along the shores of Penzhin Inlet at the head of the Sea of Okhotsk, northwestern Kamchatka. Their illustrated specimens are identical to those from the type locality in northern California. To date, there are no precise correlation data on how the Kamchatka Eocene rocks compare biostratigraphically with northeastern Pacific Eocene rocks. The presence of "*M.*" *markleyensis* in the Matilija Sandstone at Matilija Hot Springs, however, lowers the northeastern Pacific temporal range of this species into the "Transition Stage." The species previously was known only from the "Tejon Stage" in northern California.

Wenz (1939) reported the geologic range of *Melanatria* to be Paleocene?, Eocene to Recent, with all the confirmed fossil occurrences in Europe. If "*Melanatria*" *markleyensis* is proven eventually to belong to genus *Melanatria,* this species would extend the geographic range of this genus to the New World.

Family Melanopsidae Adams and Adams, 1854

Genus *Loxotrema* Gabb, 1868

TYPE SPECIES. *Loxotrema turritum* Gabb, 1868, by original designation; early to middle Eocene, California, Oregon, Washington, and Kamchatka.

Loxotrema turritum Gabb, 1868
Figures 18, 19

Loxotrema turrita Gabb, 1868:147, pl. 14, fig. 21; 1869:168, pl. 28, fig. 49; Arnold, 1909:14, pl. 4, fig. 17; Arnold and Anderson, 1910:71, pl. 26, fig. 17; Clark, 1929:pl. 10, fig. 3. Hanna, 1927: 312, pl. 50, figs. 5–8; Vokes, 1939:159, pl. 20, figs. 15–19; Schenck and Keen, 1940:pl. 24, figs. 10–13; Weaver 1942 [1943]:374, pl. 75, figs. 1–3; pl. 103, fig. 18; Devyatilova and Volobueva, 1981:114–115, pl. 9, figs. 19–23.

Struthiolaria (*Loxotrema*) *turrita* (Gabb). Tryon, 1883:196, pl. 60, fig. 95.

Loxotrema turritum Gabb. Stewart, 1927:347–348, pl. 26, figs. 3, 4; Turner, 1938:tables 2, 4, 8, p. 81, pl. 17, figs. 12, 13; Moore, 1968:26, pl.11, fig. d; Givens, 1974:70, pl.6, fig. 17. Givens and Kennedy, 1976:963, pl. 1, figs. 5–8; Squires, 1998.

Pachychilus (*Loxotrema*) *turritum* (Gabb). Wenz, 1939:686, fig. 1968.

Loxotrema cf. *L. turritum* Gabb. Jestes, 1963:225.

?*Loxotrema turritum* Gabb. Squires, 1991b:table 1, pl. 1, fig. 16.

PRIMARY TYPE MATERIAL. Lectotype ANSP 4228, designated by Stewart (1927); "Tejon Group, 10 miles west of Griswold's, between San Juan and New Idria" (Gabb, 1869:168); Domengine Formation, Vallecitos syncline area, San Benito County, central California.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 6451 and 12452.

MOLLUSCAN STAGE RANGE. "Meganos" to lower part of "Tejon."

GEOGRAPHIC DISTRIBUTION. Southern to northern California; southwestern Oregon; Crescent Bay, Olympic Peninsula, southwestern Washington; and northwestern Kamchatka.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1452.

REMARKS. This species is abundant only at locality 1450, where specimens range from 18 to 30 mm in height. At the other localities, between 4 to 10 specimens were found. Specimens are usually encased in brittle mudstone, and extraction from the bedrock almost always results in loss of the uppermost spire and anterior end of the aperture. Many of the specimens have been crushed. This turreted species is characterized by tabulate whorls, a large cylindrical body whorl with strong spiral ribs, and a notched aperture. The small nodes on the tabulate body whorl are distinct on the Matilija Hot Springs specimens and show no signs of wear resulting from postmortem transport. Squires (1998) reported also that the specimens of *Loxotrema turritum* from Matilija Hot Springs show no evidence of postmortem transport. See Squires (1998) for a review of this species.

Devyatilova and Volobueva (1981) reported this species from middle Eocene coastal-marine rocks along the shores of Penzhin Inlet at the head of the Sea of Okhotsk, northwestern Kamchatka. These rocks are within the Kamchik Formation and the lower part of the Tkapravayam subformation. The specimens they illustrated are identical to those from the type locality in central California.

Superfamily Calyptraeoidea Lamarck, 1809

Family Calyptraeidae Lamarck, 1809

Genus *Crepidula* Lamarck, 1799

TYPE SPECIES. *Patella fornicata* Linnaeus, 1758, by monotypy; Recent, eastern United States and northwestern Europe.

Crepidula inornata Dickerson, 1916
Figures 20, 21

Crepidula inornata Dickerson, 1916:489, pl. 38, figs. 5a, 5b; Lindberg and Squires, 1990:579.
Crepidula (*Spirocrypta*) *inornata* Dickerson. Vokes, 1939:165–166, pl. 21, figs. 10, 11.
Crepidula sp. Jestes, 1963:223.

PRIMARY TYPE MATERIAL. UCMP holotype 11804, Domengine Formation near Coalinga, Fresno County, central California, UCMP loc. 672.

ILLUSTRATED SPECIMEN. LACMIP hypotype 12453.

MOLLUSCAN STAGE RANGE. "Domengine" to "Transition."

GEOGRAPHIC DISTRIBUTION. Matilija Hot Springs, Ventura County, southern California; Edmonston Pumping Plant, near Grapevine, Kern County; and Coalinga area, Fresno County, central California.

LOCAL OCCURRENCE. LACMIP locs. 1444, 1445, 1446, 1450.

REMARKS. Specimens of this species are abundant at localities 1445 and 1450, where specimens range from 11 to 17 mm in length. Most are well preserved, but a few are crushed. Nearly all show delicate growth lines. At all the other localities, only single specimens were found.

Although some workers (e.g., Stewart, 1927; Turner, 1938; Hoagland, 1977) considered *Crepidula inornata* as conspecific with *C. pileum* (Gabb, 1864:137, pl. 29, figs. 233, 233a, 233b) from upper Eocene to middle Oligocene strata in California through Washington (Squires, 1987), other workers (e.g., Clark, 1938; Vokes, 1939; Kleinpell and Weaver, 1963) considered them to be separate species. *Crepidula inornata* is distinguished from *C. pileum* by having a smaller size, an elevated rather than a submarginal spire, and a bulbous penultimate whorl. The Matilija Hot Springs specimens have all the diagnostic characters of *C. inornata.* Lindberg and Squires (1990) reported this species from "Transition Stage" strata at the Edmonston Pumping Plant at the south end of the San Joaquin Valley, central California. The presence of *C. inornata* at Matilija Hot Springs is the first record of this species from brackish-marine strata.

Superfamily Naticoidea Forbes, 1838

Family Naticidae Forbes, 1838

Genus *Crommium* Cossmann, 1888

Type Species. *Ampullaria willemetii* Deshayes, 1825, by original designation; Eocene, France.

Crommium sp. cf. *C. andersoni* (Dickerson, 1914)
Figures 22, 23

ILLUSTRATED SPECIMEN. LACMIP hypotype 12454.

LOCAL OCCURRENCE. CSUN locs. 1444, 1450.

REMARKS. Specimens are rare. Four specimens were found at locality 1444 and two at locality 1450. They range from 10 to 20 mm in height, and all are crushed internal molds. They resemble *Crommium andersoni* (Dickerson, 1914:120, pl. 12, figs. 2a, 2b) from lower to middle Eocene strata of California and southwestern Oregon. Marincovich (1977:225–227, pl. 18, figs. 3–7) also illustrated this species. The Matilija Hot Springs specimens, such as *C. andersoni,* have tabulated whorls, a smooth globose body whorl, and a lowly elevated spire. Whether or not the Matilija Hot Springs specimens have a narrow umbilical slit bounded by a narrow cordlike angulation, such as that found on *C. andersoni,* cannot be determined because the anterior end of the Matilija Hot Springs specimens are either incomplete or poorly preserved. If the Matilija Hot Springs specimens are *C. andersoni,* they would be the youngest record of this species.

Genus *Neverita* Risso, 1826

TYPE SPECIES. *Neverita josephina* Risso, 1826, by monotypy; Eocene to Recent, Europe.

Neverita (*Neverita*) *globosa* Gabb, 1869
Figures 24, 25

Neverita globosa Gabb, 1869:161, pl. 27, fig. 39; Dickerson, 1916:pl. 39, figs. 5a–b; Stewart, 1927:326–327, pl. 28, fig. 6; Clark and Woodford, 1927:121–122, pl. 22, figs. 5–10; Turner, 1938:89, pl. 19, figs. 6–7, 13–15; Vokes, 1939: 169, pl. 21, figs. 9, 15–19; Schenck and Keen, 1940:pl. 24, figs. 2–5; Givens and Kennedy, 1979:tables 1–3.
Neverita weaveri Dickerson, 1915:57, pl. 4, figs. 10a-b.
Neverita nomlandi Dickerson, 1917:173–174, pl. 30, figs. 2a-b.
Polinices weaveri (Dickerson). Turner, 1938:86, pl. 20, figs. 14, 16.
Neverita globosa reefensis Vokes, 1939:169, pl. 21, figs. 24–25.

Polinices (*Neverita*) *globosa* (Gabb). Weaver, 1942 [1943]:339, pl. 68, figs. 21, 24; pl. 69, figs. 5–6; pl. 100, fig. 29.
Polinices (*Neverita*) *nomlandi* (Dickerson). Weaver, 1942 [1943]:340, pl. 69, figs. 8–9, 12.
Neverita (*Neverita*) *globosa* Gabb. Givens, 1974: 76; Marincovich, 1977:312–316, pl. 28, figs. 10–15; pl. 29, figs. 1–3; Squires, 1984:25, fig. 7g; 1987:37–38, fig. 47.
Neverita (*Glossaulax*?) *globosa* Gabb. Givens and Kennedy, 1976:965–966, pl. 2, figs. 5–14, 16, 18–19.

PRIMARY TYPE MATERIAL. MCZ holotype 27859, Domengine? Formation, 16 km west of Griswold's, on the road from San Juan to New Idria, and southeast of "Sheep Well," T 15 S, R 9 E, Priest Valley quadrangle, San Benito County, central California.

ILLUSTRATED SPECIMEN. LACMIP hypotype 12455.

MOLLUSCAN STAGE RANGE. "Meganos" through "Tejon."

GEOGRAPHIC DISTRIBUTION. San Diego, California, through southwestern Washington.

LOCAL OCCURRENCE. CSUN locs. 1444, 1450, and 1451.

REMARKS. A specimen was found at each locality. Collectively, they range from 11 to 17 mm in height. They are poorly preserved and are missing the outer lip.

Class Bivalvia Linnaeus, 1758

Subclass Pteriomorphia Beurlen, 1944

Order Arcoida Stoliczka, 1871

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Genus *Barbatia* Gray, 1847

TYPE SPECIES. *Arca barbata* Linnaeus, 1758, by original designation; Recent, Mediterranean to northwestern Africa.

Subgenus *Barbatia* s.s.
Barbatia (*Barbatia*) *morsei* Gabb, 1864
Figure 26

Barbatia morsei Gabb, 1864:216, pl. 32, fig. 286; Arnold, 1909:13, 16, pl. 3, fig. 8; Arnold and Anderson, 1910:70, 73, pl. 25, fig. 8; Hanna, 1927:272, pl. 25, figs. 2, 10, 11, 13, 14. Clark, 1929:pl. 6, fig. 3; Stewart, 1930:87, pl. 8, fig. 7.
Barbatia (*Obliquarca*) *morsei* Gabb. Vokes, 1939: 49–50, pl. 1, figs. 25, 26, 28, 29; Reinhart, 1943: 30–32, pl. 1, fig. 4.
Barbatia (*Barbatia*) *morsei* Gabb. Moore, 1983:34, pl. 5, fig. 7.

PRIMARY TYPE MATERIAL. UCMP lectotype 11984, designated by Reinhart (1943); Eocene of the San Diego region (exact locality unknown), San Diego County, southern California.

ILLUSTRATED SPECIMEN. LACMIP hypotype 12456.

MOLLUSCAN STAGE RANGE. "Domengine" to "Transition."

GEOGRAPHIC DISTRIBUTION. San Diego, Matilija Hot Springs, and Pine Mountain area, southern California; Coalmine Canyon near Coalinga, central California.

LOCAL OCCURRENCE. CSUN locs. 1444, 1450.

REMARKS. Eleven specimens were found at locality 1450, and they range from 3 to 10.3 mm in height. Three specimens were found at locality 1444. Preservation at both localities is excellent to good, although most specimens have been slightly crushed. Both right and left valves are present, but no articulated specimens were found. The thinness of the valves makes them extremely fragile, and specimens usually break apart during extraction from the rock at the outcrop.

This species is characterized by the nearness of the beak to the anterior margin. The illustrated specimen (Fig. 26) shows the exterior sculpture better than any other known specimen of this species. It shows that there can be radial ribs on the posterodorsal area and that these ribs are the widest spaced of any on the shell. This specimen, which has a sharp angle where the posterior margin meets the hinge, shows no sign of any abrasion due to postmortem transport.

The Matilija Hot Springs specimens of this species are the geologically youngest known for this species.

Order Ostreoida Férussac, 1822

Superfamily Ostreoida Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

Genus *Acutostrea* Vialov, 1936

TYPE SPECIES. *Ostrea acutirostris* Nilsson, 1827, by original designation; Upper Cretaceous, Europe and North America.

Acutostrea idriaensis idriaensis (Gabb, 1869)
Figures 27, 28

Ostrea idriaensis Gabb, 1869:203, pl. 33, figs. 103b–d; pl. 34, figs. 103, 103a; Hanna, 1927: 276, pl. 30, figs. 1–2; pl. 31, figs. 3–4; Stewart, 1930:126–127, pl. 8, fig. 3; pl. 17, fig. 1; Vokes, 1935:291–304, pl. 22–24; Turner, 1938:46, pl. 6, fig. 9; Weaver, 1942 [1943]:78–79, pl. 15, fig. 5; Schenck and Keen, 1940:pl. 23, figs. 3, 4; Givens, 1974:44; Givens and Kennedy, 1979:tables 2, 4; Squires, 1984:45, fig. 101.
Ostrea columbiana Weaver and Palmer, 1922:13–14, pl. 8, figs. 15, 16.
Ostrea oregonensis Packard, 1923:4–6, pls. 1–4.
Ostrea sp. Jestes, 1963:223, 225.

Acutostrea idriaensis idriaensis (Gabb). Moore, 1987:31–32, figs. 2, 3; pl. 14, fig. 6; pl. 16, fig. 3; pl. 29, figs. 3–5; Lindberg and Squires, 1990: 579.

Not *Ostrea idriaensis* Gabb. Devyatiliova and Volobueva, 1981:57, pl. 5, fig. 3.

PRIMARY TYPE MATERIAL. MCZ lectotype 15048, Domengine Formation, about 3 km east of New Idria, N 1/2 of section 15, T 17 S, R 12 E, Priest Valley quadrangle, San Benito County, central California.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12457 and 12458.

MOLLUSCAN STAGE RANGE. "Capay" to "Tejon."

GEOGRAPHIC DISTRIBUTION. San Diego, California, through southwestern Washington.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1453.

REMARKS. This species is one of the most ubiquitous bivalves in the restricted-coastal facies, and it is abundant in muddy rocks at all the localities, except at locality 1452 where it is rare. It is also present as a few scattered fragments in the beach and barrier-bar sandstones. At localities where it is abundant, specimens range from 25 to 75 mm in height. Preservation at all localities ranges from good to poor, and nearly all the specimens are disarticulated. They consist of only the left (lower) valve and are somewhat elongate, lowly arched, and usually have low radial ribs crossed by growth rugae. A few specimens are roundish and arched. Articulated specimens are rare.

Subclass Heterodonta Neumayr, 1884

Order Veneroida Adams and Adams, 1856

Superfamily Arcticoidea Newton, 1891

Family Trapezidae Lamy, 1920

Genus *Neotrapezium* Habe, 1951

TYPE SPECIES. *Cardita sublaevigata* Lamarck, 1819, by original designation; Recent, Indo-Pacific.

Neotrapezium californicum new species
Figures 29–33

Unio(?) *torreyensis* Hanna. Jestes, 1963:224.
Lithophaga (?) sp. Jestes, 1963:226.

DIAGNOSIS. A small-sized *Neotrapezium* with a moderately produced anterior end, usually straight posterior hinge-line area, and prominent growth lines.

COMPARISON. The new species is similar to the living *Neotrapezium liratum* (Reeve, 1843), an Indo-Pacific species introduced to various locations in the northeastern Pacific region (Bonnot, 1935 [as *Cypricardia lyrata*]; Solem, 1954; Hanna, 1966). Kira (1965:148, pl. 53, fig. 29) illustrated this species. The new species differs by having a slightly more produced anterior end.

The new species is similar to *Neotrapezium grignonensis* (Deshayes, 1824:64–65, pl. 9 figs. 18–19) from middle and upper Eocene (Lutetian and Bartonian stages) strata of the Paris Basin, France. Cossmann and Pissarro (1904–1906:pl. 15, figs. 63–1 through 63–10) figured this Paris Basin species, as well as seven other closely related "species" from the same region. Le Renard and Pacaud (1995) regarded *N. grignonensis* as conspecific with all of these seven other "species." The new species is similar to *N. grignonensis* in that there is a range in morphology from elongate-ovate to subquadrate, but the new species differs by having an anterior end that is more produced, a posterior end that is never as produced, growth lines that are usually more accentuated, and a shell that never is as narrow or smooth as in some specimens of *N. grignonensis*.

DESCRIPTION. Small-sized (up to 13.2 mm high), thin-shelled, moderately elongate-ovate to subquadrate, equivalved, and inequilateral. Ligament external, opisthodetic. Beaks near anterior end, prosogyrous, and moderately elevated. Anterior margin slightly pointed; posterior hinge-line straight to slightly arched. Posterior margin steeply sloping. Very faint radial lirae rare on posterior area. Right valve with two cardinal teeth and long posterior lateral. Left valve with long posterior socket (cardinals unseen). Growth lines prominent, commonly clustered into bands; on a few specimens growth-line bands merge into very fine concentric ribs, strongest on posterior area and/or medial area. Growth rugae near ventral margin on some specimens. Irregular to distorted growth on some specimens.

HOLOTYPE DIMENSIONS. Height 7.7 mm, length 13.9 mm.

PRIMARY TYPE MATERIAL. LACMIP holotype 12459 (illustrated), LACMIP paratypes 12460 to 12463 (all illustrated); all from CSUN loc. 1450, except paratype 12462 (from CSUN loc. 1445).

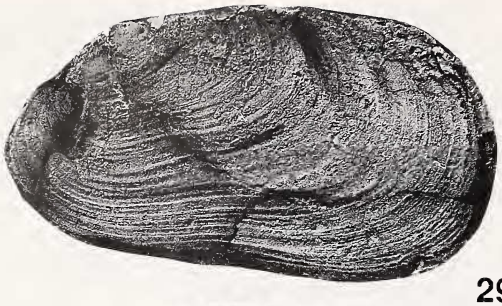
TYPE LOCALITY. LACMIP loc. 1450.

MOLLUSCAN STAGE RANGE. "Transition."

GEOGRAPHIC DISTRIBUTION. Upper part of Matilija Sandstone at Matilija Hot Springs area.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1453.

REMARKS. The new species is abundant at locality 1450, where specimens range from 1.3 to 13.2 mm in height. Specimens are uncommon to rare at the other localities. Preservation is generally good, and most are single valves. At locality 1450, however, about 13% of the specimens are articulated. Nearly all specimens are extensively crushed. The new species shows a considerable degree of variation in shape, based on 56 specimens preserved well enough to determine valve shape. Of these, 52 (93%) are elongate-ovate, and the other 4 (7%) are subquadrate. A few of the latter even show distorted (irregular or disjunct) growth, where the growth lines delineate a progression of different shapes on a valve. Consequently, the valve



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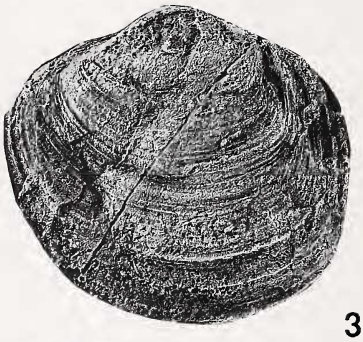

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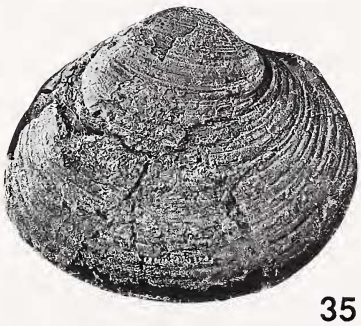

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appears to be a composite of several individual valves, one on top of the other. An example is illustrated in Figure 31. Modern species of *Neotrapezium* are known to be nestlers or shallow infauna, and the nestling mode of life commonly causes distortion during growth (Kira, 1965; Morton, 1979). Of the 52 elongate-ovate specimens mentioned above, 25 have pronounced growth lines, 20 are somewhat smooth, and 7 have growth lines that are very accentuated posteriorly. Only the holotype of the new species shows any radial sculpture, and it is very faint. The subquadrate-shaped valves of the new species all have pronounced growth lines. The new species is the first record of *Neotrapezium* in the fossil record of North America. Although *Trapezium* (*Schedotrapezium*) *carinatum* Gabb (1864:170, pl. 23, fig. 150; Stewart, 1930:174–175, pl. 5, fig. 5; pl. 17, fig. 4) was reported from Upper Cretaceous (Campanian Stage fide LouElla Saul, personal communication, 1997) rocks in Placer County, northern California, this species is no longer considered to belong to the family Trapezidae and is now placed (Keen, 1969a) in *Schedotrapezium* Stewart, 1930, of the family Arcticidae Newton, 1891.

A bivalve referred to as *Trapezium claibornense* Dall (1900a:1498, pl. 43, figs. 9, 10; Harris, 1919: 154, pl. 48, figs. 3, 4) was reported as a very rare species from middle Eocene (Claiborne Stage) strata of Alabama. Maestrati and Lozouet (1995), however, regarded Dall's species as probably being an astartid. The new species differs from Dall's species by having a lower height relative to the length of the valves, more variable concentric sculpture, a more rounded posterior end, and a posterior margin that is not obliquely angular.

The new species is also the first record of subgenus *Neotrapezium* in the fossil record of North America. This article follows Maestrati and Lozouet (1995) and Coan and Scott (1997) in regarding *Neotrapezium* as a distinct genus within the family Trapezidae.

ETYMOLOGY. The new species is named for the state of California.

Superfamily Corbiculoidea Gray, 1847

Family Corbiculidae Gray, 1847

Genus *Corbicula* Mergele von Mühlfeld, 1811

TYPE SPECIES. *Tellina fluminalis* Müller, 1774; Recent, Africa, Asia, Australia, and introduced into the United States of America (Brandt, 1974).

Corbicula jestesi new species
Figures 34–39

Corbicula williamsoni Anderson and Hanna, 1925. Jestes, 1963:223.
Pitar sp. Jestes, 1963:222.
Macrocallista sp. Jestes, 1963:223.

DIAGNOSIS. A *Corbicula* with circular-rounded shape, moderately inflated beaks, moderately strong concentric ribbing, and a very slight umbonal ridge.

COMPARISON. The new species was compared to all other fossil species of *Corbicula* known from the northern Pacific region (including Kamchatka). The new species is most similar to *C. williamsoni* Anderson and Hanna (1925:164–165, pl. 1, fig. 4; pl. 3, fig. 2) from the "Tejon Group" at Grapevine Canyon. Only a single specimen, a left valve, is known of this species. The new species differs from *C. williamsoni* by having concentric ribbing over the entire left valve (not just the anterior half of the valve), more closely spaced and weaker concentric ribbing, a much weaker umbonal ridge, and a less sloping anterior margin. The other northern Pacific Eocene *Corbicula* species differ from the new species by having much more produced beaks, usually more central beaks, and nearly obsolete sculpture.

DESCRIPTION. Medium sized (up to 27 mm high), equivalved, slightly inequilateral; circular-rounded shape, longer than high. Thick shelled. Beaks prosogyrous, slightly anterior of center, moderately inflated, and elevated above hinge line. Very slight posterior umbonal ridge. Anterior dorsal margin gently sloped and concave; posterodorsal margin straight. Anterior, ventral, and posterior margins broadly and regularly rounded. Posterior very slightly produced on some specimens. Three divergent cardinal teeth in each valve, middle tooth bifid in right valve. Left valve with a long anterior and a long posterior lateral tooth, the latter minutely serrated. Right valve with long anterior lateral socket; posterior part of hinge area unknown. Entire external surface of both valves with moderately strong, closely spaced concentric ribbing.

HOLOTYPE DIMENSIONS. Height 18.5 mm, length 22.6 mm (a "butterflied" specimen consisting of both valves).

PRIMARY TYPE MATERIAL. LACMIP holotype 12464 (illustrated), LACMIP paratypes 12465 to 12468 (all illustrated); all from CSUN loc. 1445.

TYPE LOCALITY. CSUN loc. 1445.

←

Figures 29–38. Bivalves from Matilija Hot Springs area upper part of Matilija Sandstone. All specimens coated with ammonium chloride. **29–33.** *Neotrapezium californicum* new species, CSUN loc. 1450, unless otherwise indicated. **29.** Left valve, ×4.3, LACMIP holotype 12459. **30.** Left valve, ×3.6, LACMIP paratype 12460. **31.** Right valve, ×2.9, LACMIP hypotype 12461. **32.** Dorsal view showing ligamental area, LACMIP paratype 12462, ×2.4, CSUN loc. 1445. **33.** Right-valve hinge, ×6.3, LACMIP paratype 12463. **34–39.** *Corbicula jestesi* new species, CSUN loc. 1445. **34.** Left valve, ×1.8, LACMIP paratype 12465. **35.** Right valve, ×2, LACMIP holotype 12464. **36.** Left-valve hinge, ×2.7, LACMIP paratype 12466. **37.** Right-valve hinge, ×3.2, LACMIP paratype 12467. **38, 39.** Left-valve hinge, LACMIP paratype 12468. **38.** ×3. **39.** Enlargement (of a portion of Figure 38) showing serrations, ×10.

MOLLUSCAN STAGE RANGE. "Transition."

GEOGRAPHIC DISTRIBUTION: Upper part of Matilija Sandstone at Matilija Hot Springs.

LOCAL OCCURRENCE. CSUN locs. 1445, 1452.

REMARKS. Specimens are abundant at CSUN locality 1445, where they range from 12.5 to 27 mm in height. Most are single valves, but they are unbroken and unworn. Specimens are rare at CSUN loc. 1452.

Worldwide, the temporal range of *Corbicula* is Early Cretaceous to Recent (Keen and Casey, 1969). On the Pacific coast of North America, the only Cretaceous *Corbicula* are two Late Cretaceous species. One is Turonian in age and the other is Maastrichtian in age (Dailey and Popenoe, 1966). No Paleocene *Corbicula* species are known from this area. Only three species of northern Pacific Eocene *Corbicula* are known to be older than the new species. They are *C. oregonensis* Turner, 1938, from lower Eocene ("Capay Stage") rocks now assigned to the Whitetail Ridge Formation near Glide in southwestern Oregon; *C. triangula* Volobueva in Devyatilova and Volobueva, 1981, from lower Eocene rocks of the Central Amaam subformation in the Koryak Uplands north of Kamchatka; and *C. carlosensis* Vokes, 1939, from middle Eocene ("Domengine Stage") rocks within the Domengine Formation in central California. The highest number of northern Pacific Eocene *Corbicula* species are found in middle to upper Eocene rocks in Washington (Weaver, 1942 [1943]) and in middle Eocene rocks of northwestern Kamchakta (Devyatilova and Volobueva, 1981).

ETYMOLOGY. The species is named for Edward C. Jestes, who did the initial paleontological investigations of the restricted-coastal facies at Matilija Hot Springs and who found many of the specimens of this new species.

Superfamily Veneroidea Rafinesque, 1815

Family Veneridae Rafinesque, 1815

Genus *Pelecyora* Dall, 1902

TYPE SPECIES. *Cytherea hatchetigbeensis* Aldrich, 1886; Eocene, Wilcox, Alabama.

Pelecyora aequilateralis (Gabb, 1869)
Figures 40–41

Venus aequilateralis Gabb, 1869:184, pl. 30, fig. 76; Dickerson, 1916:pl. 37, figs. 2a, 2b.
Pitaria aequilateralis (Gabb). Hanna, 1927:288, pl. 39, figs. 1–5, 9, 12.
Pelecyora aequilateralis (Gabb). Stewart, 1930: 237–238, pl. 8, fig. 13; Vokes, 1939:87, pl. 14, figs. 4, 6, 7, 8, 11; Weaver, 1942 [1943]:194, pl. 45, fig. 9; pl. 46, figs. 3, 6; pl. 104, fig. 6; Givens and Kennedy, 1979:table 2.
Pelecyora aequilateralis (Gabb) var. Turner, 1938: 57, pl. 10, figs. 1–4.
Spisula (?) sp. Jestes, 1963:224, 226.
Pitar sp. Jestes, 1963:225.
Thyasira (?) sp. Jestes, 1963:226.
(?)*Venus* (*Antigona*) sp. Jestes, 1963:227.

PRIMARY TYPE MATERIAL. MCZ lectotype 15039, designated by Stewart (1930); Delmar? Formation, San Diego area (exact location unknown), San Diego County, southern California.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12469 and 12470.

MOLLUSCAN STAGE RANGE. "Domengine" to "Transition."

GEOGRAPHIC DISTRIBUTION. San Diego, southern California, to southwestern Oregon.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1453, and scattered coquinas.

REMARKS. Specimens are extremely abundant at localities 1444, 1446, and 1450. At the first two localities, specimens range from 6 to 24 mm in height. At locality 1450, they range from 1.5 to 20 mm in height. Preservation at these three localities is excellent to good, although there are some internal molds. Many specimens are single valves, but articulated specimens are common. At the other main localities, *Pelecyora aequilateralis* is common to rare. Coquinas consisting almost entirely of this species are, however, scattered throughout the section. One of the best examples is the coquina bed immediately below locality 1453.

The specimens of *Pelecyora aequilateralis* in the study area show variation in overall shape of the valves, as well as in the strength of the concentric ribbing, but this species is characterized by such variation (Hanna, 1927; Turner, 1938; Vokes, 1939).

Superfamily Tellinoidea Blainville, 1814

Family Tellinidae Blainville, 1814

Genus *Tellina* Linnaeus, 1758

TYPE SPECIES. *Tellina radiata* Linnaeus, 1758, by subsequent designation, Children, 1823; Recent, Caribbean.

"*Tellina*" *joaquinensis* Arnold, 1909
Figures 42–43

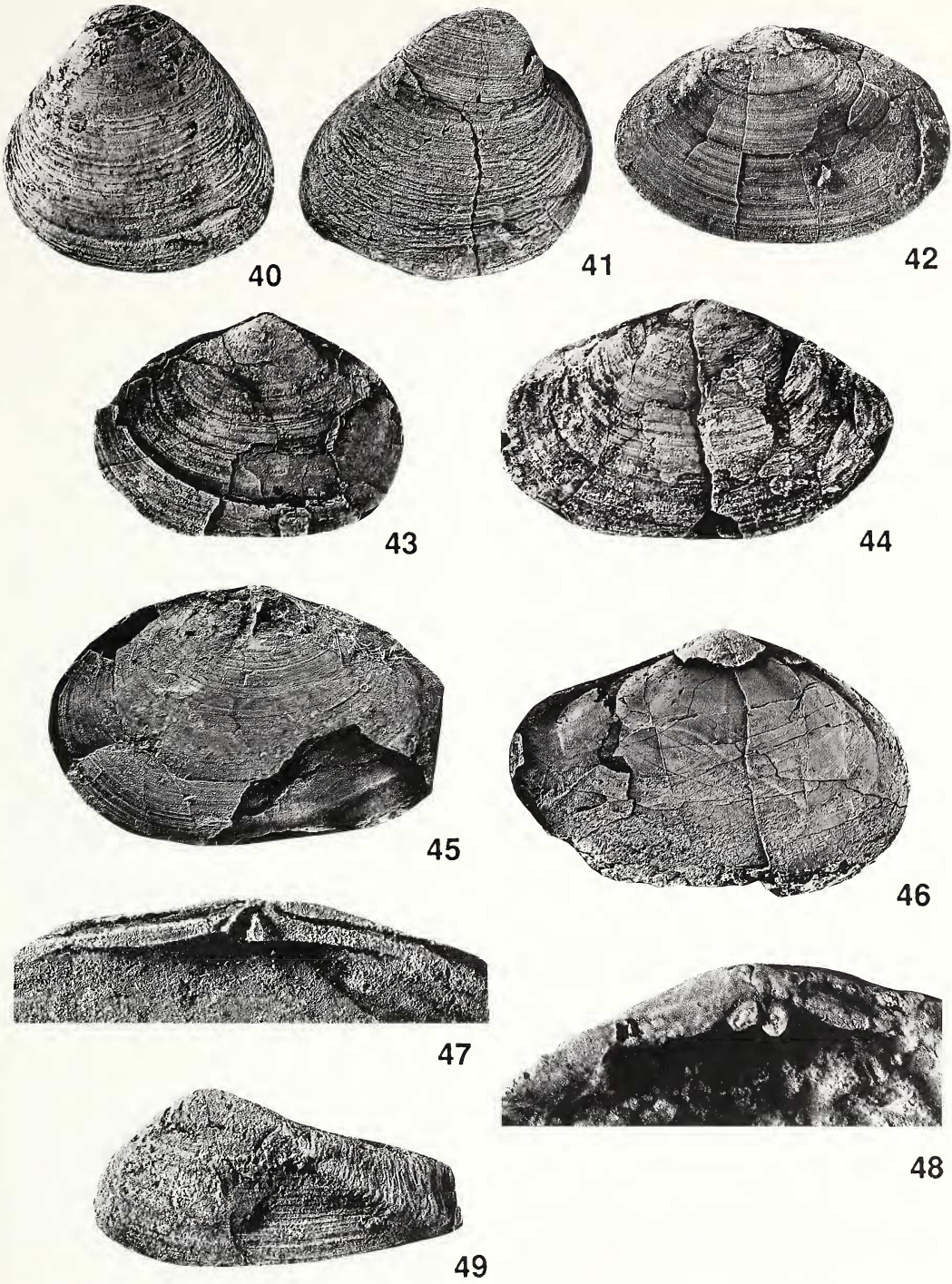
Tellina joaquinensis Arnold, 1909:49, pl. 2, fig. 11; Arnold and Anderson, 1910:70, pl. 24, fig. 11. Vokes, 1939:90, pl. 14, figs. 15, 19, 20.
Tellina sp. Jestes, 1963:222 (in part).
Gari sp. Jestes, 1963:226.
Tellina (?) sp. Jestes, 1963:225.

PRIMARY TYPE MATERIAL. USNM holotype 165619, Domengine Formation, Fresno County, central California, USGS loc. 4801.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12471 and 12472.

MOLLUSCAN STAGE RANGE. "Domengine" through "Transition."

GEOGRAPHIC DISTRIBUTION. Matilija Hot



Figures 40–49. Bivalves from Matilija Hot Springs area upper part of Matilija Sandstone. All specimens coated with ammonium chloride. **40–41.** *Pelecyora aequilateralis* (Gabb, 1869), CSUN 1450. **40.** Left valve, ×2.7, LACMIP hypotype 12469. **41.** Right valve, ×2.8, LACMIP hypotype 12470. **42–43.** "*Tellina*" *joaquinensis* Arnold, 1909. **42.** Left valve, ×3, LACMIP hypotype 12471, CSUN loc.1445. **43.** Right valve, ×2, LACMIP hypotype 12472, CSUN loc. 1445. **44–48.** "*Tellina*" *domenginensis* Vokes, 1939. 44. Left valve, ×1.5, LACMIP hypotype 12473, CSUN loc. 1445. 45. Left valve showing concentric ribs near umbo, posterior margin incomplete, ×2.5, LACMIP hypotype 12474, CSUN loc. 1450. 46. Right valve, internal mold showing pallial sinus, ×2.2, LACMIP hypotype 12475. 47. Latex peel of internal mold of left-valve hinge (incomplete), ×3.6, LACMIP hypotype 12476, CSUN loc. 1450. **48.** Right-valve hinge (incomplete), ×6, LACMIP hypotype 12477, CUN loc. 1446. **49.** *Cuneocorbula torreyensis* (Hanna, 1927), left valve, ×5.1, LACMIP hypotype 12478, CSUN loc. 1445.

Springs, southern California; Coalmine Canyon, central California; and possibly Middle Fork of the Coquille River, southwestern Oregon.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1446, 1450, 1451, 1452, 1453.

REMARKS. This species is the only mollusk found at all of the six main localities in the restricted-coastal facies at Matilija Hot Springs. Specimens are abundant at localities 1445 and 1450 and common to uncommon at the other localities. At locality 1445, specimens range from 10 to 20 mm in height, and at locality 1450 they range from 13 to 22 mm in height. Preservation is usually poor. Nearly every specimen has been crushed. Articulated specimens are plentiful, especially at locality 1445. A specimen at this latter locality has a naticid borehole.

Arnold (1909) was somewhat contradictory in his description of this species. He stated that it is inequilateral, but in an accompanying paragraph he reported that it has approximate bilateral symmetry. The Matilija Hot Springs specimens confirm the latter. In fact, on some specimens, this bilateral symmetry makes it difficult to ascertain which is the left valve and which is the right valve.

I use quotation marks for the generic assignment of this tellinid. The species cannot be assigned with certainty to *Tellina* because the hinge is not known.

"*Tellina*" *joaquinensis* differs from "*T.*" *domenginensis* by having a much less elongate shape, less inflated and thinner valves, an absence of concentric ribs near the umbones, and a rounded rather than a pointed posterior.

Turner (1938:61, pl. 7, fig. 9) tentatively reported (as *Tellina* cf. *joaquinensis*) a single, poorly preserved specimen of this species in Eocene rocks along the Middle Fork Coquille River, Coos County, southwestern Oregon.

The presence of "*Tellina*" *joaquinensis* at Matilija Hot Springs is the youngest and southernmost record of this species.

"*Tellina*" *domenginensis* Vokes, 1939

Figures 44–48

Tellina domenginensis Vokes, 1939:91, pl. 14, figs. 12, 14, 16, 18.
Tellina sp. Jestes, 1963:222 (in part).
Gari sp. Jestes, 1963:223.

PRIMARY TYPE MATERIAL. UCMP holotype 15694, UCMP loc. 3315; UCMP paratypes 15695, 15696, both from UCMP loc. A-975; UCMP paratype 15697, UCMP loc. A-1220; all from the Domengine Formation, Fresno County, central California.

ILLUSTRATED SPECIMENS. LACMIP hypotypes 12473 to 12477.

MOLLUSCAN STAGE RANGE. "Domengine" through "Transition."

GEOGRAPHIC DISTRIBUTION. Matilija Hot Springs, southern California, and between Oil City and Domengine Creek on west side of San Joaquin Valley, north of Coalinga, central California.

LOCAL OCCURRENCE. CSUN locs. 1444, 1445, 1450.

REMARKS. Specimens are common only at locality 1450, where they range from 12 to 20 mm high. A few specimens are articulated. Specimens are rare at the other two localities. Study area specimens reveal new information about this species' morphology, both exterior and interior. Fine concentric ribs are present near the umbones, although Vokes (1939) reported that the surface ornamentation consists only of coarse concentric growth lines. The pallial sinus of the right valve is revealed for the first time. It is broadly rounded, the dorsal margin ascends posteriorly, and the anterior margin is not close to the anterior adductor scar (Fig. 46). The relationship between the ventral margin of the right-valve pallial sinus and the pallial line is not clear, but they seem to be coalescent. The shape of the left-valve pallial sinus remains unknown. The cardinal teeth of both valves are also revealed for the first time. The left-valve cardinal teeth are divergent, with the anterior tooth strong and the posterior tooth very thin and lamellar (Fig. 47). The cardinal teeth on the right valve are both strong (Fig. 48), but whether or not these teeth are bifid cannot be determined. Unfortunately, poor preservation prevents study of the rest of the hingeline, where lateral teeth might be present. Until the presence of lateral teeth is confirmed, the species cannot be assigned with certainty to *Tellina*.

Among the tellinids, "*Tellina*" *domenginensis* has some important similarities to the extant *Peronidia albicans* (Gmelin, 1791; Afshar, 1969:84, pl. 35, figs. 1–5), which is the type species of *Peronidia* Dall, 1900b. Both have the following features: an ovate-trigonal shape with nearly central umbones; the posterior cardinal of the left valve is thin, lamellar, and mostly fused with the nymph; the posterior cardinal of the right valve is larger than the anterior one; and the pallial sinus is large and does not touch the anterior adductor scar.

There is also a close resemblance between "*Tellina*" *domenginensis* and the flat, almost equilateral *Peronidia nysti* (Deshayes, 1860; Báldi, 1973:225–226, pl. 21, figs. 1–2, 4) from upper Oligocene rocks in Hungary. Only the external features are known for *P. nysti,* and "*T.*" *domenginensis* differs from it by having concentric ribs near the umbones and a posterior margin that is rounded rather than slightly angular.

Better specimens of "*Tellina*" *domenginensis* are needed to determine whether or not this species is related to *Peronidia*. Additionally, there has been little agreement on the taxonomic position of *Peronidia*. It has been regarded as a subgenus of *Tellina* by some workers (Keen, 1969b; Coan, 1971; Coan and Scott, 1997); as a subgenus of *Macoma* by Afshar (1969); and as a subgenus of *Angulus* by Báldi (1973).

The presence of "*Tellina*" *domenginensis* at Ma-

tilija Hot Springs is the youngest and the southernmost record of this species.

Subclass Asthenodonta Dall, 1895

Order Myoida Goldfuss, 1820

Suborder Myina Goldfuss, 1820

Superfamily Myoidea Lamarck, 1809

Family Corbulidae Lamarck, 1818

Genus *Cuneocorbula* Cossmann, 1886

TYPE SPECIES. *Corbula pelseneeri* Glibert and van de Poel, 1966 [= *Corbula biangulata* Deshayes, 1861]; upper Paleocene (Thanetian Stage), Paris Basin, France.

Cuneocorbula torreyensis (Hanna, 1927)
Figure 49

Corbula torreyensis Hanna, 1927:296–297, pl. 44, figs. 6–10, 15–16; Clark and Vokes, 1936:875, figs. 9, 11; Turner, 1938:66, pl. 8, figs. 6, 7; Weaver 1942 [1943]:259–260, pl. 61, fig. 12.
Cuneocorbula torreyensis (Hanna). Vokes, 1939: 101–102, pl. 16, figs. 16, 20, 21; Jestes, 1963: 222, 225; Givens and Kennedy, 1979:table 2.
Corbula (*Cuneocorbula*) *torreyensis* Hanna. Givens, 1974:58.

PRIMARY TYPE MATERIAL. UCMP holotype 31115; UCMP paratypes 31116–31119; all from Delmar Formation, San Diego area, San Diego County, southern California, UCMP loc. 3981.

ILLUSTRATED SPECIMEN. LACMIP hypotype 12478.

MOLLUSCAN STAGE RANGE. "Domengine" to "Transition."

GEOGRAPHIC RANGE. San Diego and Matilija Hot Springs, southern California; Vallecitos Syncline, central California; and Glide, southwestern Oregon.

LOCAL OCCURRENCE. CSUN locs. 1445, 1452, and scattered coquinas.

REMARKS. Specimens are abundant at localities 1445 and 1452. At both localities, specimens range from 5 to 6 mm in height, and preservation is good. Specimens are unworn, unbroken, and mostly single valves. Articulated specimens are very rare. Throughout the section, specimens of *Cuneocorbula torreyensis* form coquinas consisting almost entirely of compacted specimens of this species.

LOCALITIES

CSUN LOCALITIES

All are in the upper part of the Matilija Sandstone (lower middle Eocene "Transition Stage") in the NE 1/4 of the SE 1/4 of section 29, T 5 N, R 23 W, USGS topographic quadrangle, Matilija, California, 7.5 minute, 1952 (photorevised 1967), 1:24,000.

1444. [= LACMIP 16961]. Roadcut on north side of a short, paved road that leads from Highway 33 to Matilija Hot Springs, about 48 m (157 ft.) west of sharp bend in this road, near bottom of restricted-coastal facies.

1445. [= LACMIP 24259]. Roadcut on north side of a short, paved road that leads from Highway 33 to Matilija Hot Springs, about 26 m (85 ft.) west of sharp bend in this road.

1446. [= LACMIP 24258]. Roadcut on north side of a short, paved road that leads from Highway 33 to Matilija Hot Springs, about 12 m (39 ft.) west of sharp bend in this road.

1450. [= LACMIP 16963]. On south bank of North Fork of Matilija Creek, near bottom of restricted-coastal rocks, about 260 m (852 ft.) west of junction of Highway 33 and a short, paved road that leads to Matilija Hot Springs.

1451. [= LACMIP 16964]. On south bank of North Fork of Matilija Creek, about 250 m (820 ft.) west of junction of Highway 33 and a short, paved road that leads to Matilija Hot Springs.

1452. [= LACMIP 16965]. On south bank of North Fork of Matilija Creek, about 230 m (754 ft.) west of junction of Highway 33 and a short, paved road that leads to Matilija Hot Springs.

1453. [= LACMIP 16962]. Roadcut on north side of a short, paved road that leads from Highway 33 to Matilija Hot Springs, about 43 m (141 ft.) west of sharp bend in this road.

LACMIP LOCALITY

7226. In the vicinity of Beartrap Creek, just east of hill 4560 along an unmaintained trail and downslope for about 15 m (49ft) from trail, at section line between sections 24 and 25, T 7 N, R 23 W, USGS topographic quadrangle, Reyes Peak, California, 7.5 minute, 1943, 1: 24,000.

UCMP LOCALITIES

672. SE 1/4 of the NW 1/4 of section 24, T 18 S, R 14 E, USGS topographic quadrangle, Joaquin Rocks, California, 7.5 minute, 1969, 1:24,000.

3315. Base of Domengine Formation, immediately south of Domengine Creek, USGS topographic quadrangle, Domengine Ranch, California, 7.5 minute, 1956 (photorevised 1979), 1:24,000.

3981. At 15 m (50 ft.) above high-tide level in a small gulley .4 km (.24 mi.) south of mouth of Soledad Valley, USGS topographic quadrangle, Del Mar, California, 7.5 minute, 1967, 1:24,000.

3992. In sea cliff about .8 km (.5 mi.) south of the mouth of Soledad Valley at high-tide level, USGS topographic quadrangle, Del Mar, California, 7.5 minute, 1967, 1:24,000.

5084. At 2.55 inches due north of top of the "S" of Soledad Mountain, in sea cliff, elevation 3 m (10 ft.), fossils in the conglomerate above the mudstone, USGS topographic quadrangle, La Jolla, California, 7.5 minute, 1967, 1:24,000.

A-975. Second "reef" above base of Domengine Formation in draw across ridge to south of Big Tar Canyon, USGS topographic quadrangle, Garza Peak, California, 7.5 minute, 1953, 1:24,000.

A-1220. At base of Domengine Formation in small draw cutting long ridge, 53 m (175 ft.) north of line between sections 9 and 16, T 19 S, R 15 E, USGS topographic quadrangle, Domengine Ranch, California, 7.5 minute, 1956 (photorevised 1979), 1:24,000.

A-1297. From sandstone cliff on northeast bank of

Pleasants Creek opposite Brink ranch house about 1.2 km (.75 mi.) east of bench mark 258, and 3.2 km (2 mi.) south of Putah Creek, USGS topographic quadrangle, Mt. Vaca, California, 7.5 minute, 1951 (photorevised 1968), 1:24,000.

UCR LOCALITY

4747. Just east of elevation 4072 on ridge south of mouth of Beartrap Creek, 594 m (1948 ft.) north and 457 m (1498 ft.) east of southwest corner of section 23, T 7 N, R 23 W, USGS topographic quadrangle, Reyes Peak, California, 7.5 minute, 1943, 1:24,000.

USGS LOCALITY

4801. About 4.8 km (3 mi.) northwest of Coalinga, at Coalmine Canyon in NW 1/4 of section 26, T 20 S, R 14 E, USGS topographic quadrangle, Alcalde Hills, California, 7.5 minute, 1969, 1:24,000.

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